1984-85 BACTERIOLOGICAL WATER QUALITY AT BELLEVILLE, BAY OF QUINTE

Ministry of the Environment
Ontario

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WATER QUALITY at BELLEVILLE,
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1.0 CONCLUSIONS

1. The major wet weather bacterial loading to the Bay of Quinte at Belleville was found to originate from the Moira River. Contributing to this loading are the city storm sewers discharging to the river as well as runoff entering the river at the Corby Distillers Ltd. outfall north of the city.

2. It was found impossible to rank the sewers quantitatively in order of importance of wet weather contributions to Moira River pollution, as flow rates could not be measured accurately, and both flow rates and bacterial levels varied rapidly with time. Data collected during the 1985 surveys suggest the following sewers or groups of sewers are major contributors: (a) sewers in the College St. area; (b) a ditch adjacent to the CN bridge on the west side of the river; (c) sewers close to and just upstream of the Pinnacle St. bridge; (d) submerged sewers draining the lower downtown area east of the river; (e) several sewers draining to the west side of the river between Bridge St. and Henry St.

3. The Palmer Road storm sewer west of the Moira River at times had high bacterial concentrations, which can be of concern if flooding problems are not corrected.

4. Most Bayfront storm sewers, which generally drain via ditches to the Bay, show high bacterial counts but very low to negligible flows except immediately after rainfall. High bacterial counts observed in 1984 just west of the Bakelite plant suggested a source of contamination in this area, but 1985 surveys were unable to locate a source.

5. Even under dry weather conditions, most of the Moira River within city limits was found to contain high fecal coliform levels significantly above the Provincial Water Quality Objectives for body contact recreation. This "base level" is reached within 1 or 2 days after cessation of rainfall. Sewers at Church St., Pinnacle St., Bridge St. (east side) and a ditch on the west side at the CN tracks were observed to have significant dry weather flow and high bacterial counts, and are the likely sources of this contamination.

6. At most sampling points, E. coli accounted for nearly all the fecal coliforms present. This suggests that the sources are largely related to human and/or animal fecal wastes. Several storm sewers were exceptions.

7. Fecal coliform/fecal streptococcus (FC/FS) ratios varied considerably with time, and some locations displayed high FC/FS ratios one day and low ratios on another day. Considerable spatial variability (e.g. one transect to the next, or within a transect) was also observed. Sewers with FC/FS ratios that were high enough to indicate possible human contamination included a ditch near the CN tracks on the west side of the river, several downtown area sewers on the east side of the river below Bridge St., and one bayfront sewer near Belleville Hospital.

8. Riverside Beach exhibited unacceptably high bacterial levels during wet weather and occasionally during dry weather. Two storm sewers north of the beach on the east side of the river, plus runoff at the Corby Distillers Ltd. outfall are thought to be responsible.

9. Both Health Unit and Ministry of the Environment data indicate that the Zwick Island beach has fecal coliform levels within Provincial Objectives nearly all the time.

10. In addition to the beaches, potential effects on recreational activity exist in the lower river, due to high fecal coliform counts which persist much of the time in this area.

11. The Belleville STP effluent was found to be highly variable in bacterial levels, and at times may be an important source of Bay pollution.

12. In 1984, the plume of degraded bacterial quality in the Bay of Quinte was only slightly smaller than the largest plume observed in 1981. This indicates that the expansion of the Belleville STP has produced little or no improvement in Bay water bacteriological quality. The maximum extent of the plume occurred one to two days after the heaviest rainfall.

2.0 RECOMMENDATIONS

1. The City of Belleville should direct effort towards removal of dry-weather bacterial inputs to the Moira River including the ditch at the CN bridge, Church St., Pinnacle St., and an east-side downtown area submerged outfall. A comprehensive dry weather survey should be initiated by the City to address this and other sources, with specific attention to the location and correction of illegal cross-connections and sanitary inputs.

2. Inputs of bacterial contamination to the Corby Distillers Ltd. outfall should be investigated by the Ministry Southeastern Region, and corrective measures initiated.

3. Chlorination practices at the Belleville STP should be reviewed to ensure that continuous high disinfection efficiency occurs.

4. The City of Belleville, in consultation with the Ministry (Southeastern Region), should consider expanding pumping stations and trunk sewer capacities as needed to handle peak flows within the expanded STP capacity. This includes the Dundas St. W. pumping station.

5. A schedule of action programs for the affected areas of the Moira River and Bay of Quinte should be developed by the City of Belleville and the Ministry Southeastern Region, in cooperation with the Water Resources Branch. This should include a periodic surveillance program to be conducted by the Great Lakes Section, to assess the effectiveness of remedial measures. This action program should be presented by the Municipality to its public for review and agreement.

3.0 INTRODUCTION

In 1981, the Great Lakes Section, in co-operation with the Southeastern Region of the Ministry of the Environment, undertook a study of the bacteriological water quality of the Bay of Quinte, including Trenton, Belleville, Picton and Deseronto (Griffiths, 1984). The purposes of the 1981 study included: documenting selected STP and river sources of bacterial inputs discharging into the Bay of Quinte; assessing the effects of these inputs on the receiving waters. In addition, two area bathing beaches (Zwick Island and Government Dock) were monitored regularly by the Hastings and Prince Edward Counties Health Unit.

An intensive grid of stations in the Belleville area plus background stations was sampled six times over an 18-day period in August 1981 under varying meteorological conditions ranging from no precipitation within the previous 3 days to 40 mm rainfall on the day of sampling. Effluent samples were also collected from the Belleville STP.

The results of this survey showed extensive zones of bacteriological degradation following precipitation episodes. Following a rainfall of 15 mm on two preceding days, the zone with fecal coliform counts above 100 organisms /100 mL extended eastward from the Moira River mouth approximately 3 km. During low precipitation periods, the degraded zone was confined chiefly to the Moira River mouth. It was suggested that the chief source of the bacteriological impairment was raw sewage bypassing under runoff conditions.

Health unit data in 1982 showed that the Zwick Island and Government Dock beaches exhibited fecal coliform counts above 100 organisms/100 mL 46 and 35% of the time, respectively, with seasonal geometric means of 91 and 58 organisms/100 mL. The Zwick Island data may have been increased by bridge construction activity. The Government Dock location was shown to be affected by the Moira River plume according to 1981 results.

In 1981, the design capacity of the Belleville STP was 36,400 m^3/d (8 MGD), and the peak capacity was 54,500 m^3/d (12 MGD). In the summer of 1984, this plant was expanded to provide complete treatment for 54,500 m^3/d, and primary treatment for average flows of 109,100 m^3/d (24 MGD) and peak flows of 163,500 m^3/d (36 MGD). Construction of an extended diffuser outfall 1350 mm (4.4 ft) in diameter including a diffuser section 142.71 m (468 ft) long was completed in fall 1984, after the 1984 field survey was completed. With the expansion in place, the incidence of raw sewage bypassing during rainfall events was expected to be considerably reduced, if not eliminated.

As a component of the action plan developed following reporting of the earlier surveys (Griffiths, 1984), the Ministry's Southeastern Region requested that the Great Lakes Section perform a bacteriological survey following completion of the STP expansion. The purpose of this survey was to assess the effectiveness of the recent STP improvements on receiving water quality, and to locate additional sources of bacterial impairment (such as storm sewer overflows) in order that additional recommendations for improving receiving water quality may be formulated.

Prior to the 1985 survey, another problem associated with Belleville's storm sewers was identified as backups and flooding in some areas of the city, most noteably the Dundas St. West - Palmer Road area. An unmanned pumping station at this intersection is apparently unable to cope with runoff produced by heavy rainfall. As concern was expressed about the potential for disease related to stormwater backups, sampling of this outfall was undertaken during the 1985 survey.

4.0 SURVEY DESIGN

4.1 1984

The grid of sampling stations was designed to provide coverage of the Belleville area of the Bay of Quinte, including areas which might be affected by the Moira River, storm sewer outfalls, the Belleville STP outfall and the Bakelite Plant industrial outfall. The sampling grid used in July 1984 is shown in Figure 1 and consists of the following components:

(a) Bay stations: The sampling grid used in 1981 was modified to provide more comprehensive coverage of the Moira River mouth and Zwick Island beach vicinity, as well as upstream and downstream background transects in area not expected to be impacted.

(b) Storm sewer outfalls: Nine outfalls or ditch locations draining to the Bay of Quinte, plus five locations draining to the Moira River were sampled. One ditch (05-12) which drains a former sanitary landfill area was also sampled. Flow rates were estimated where possible from the speed and cross-section of water flow.

(c) Beach locations. Four locations at Riverside Beach (two on each side of the river), and five locations at the Zwick Island beach, were sampled once daily using Health Unit procedures (0.3 m from surface at approximately 1 m total water depth).

(d) River transects: Two transects of three stations each were sampled daily. One was located upstream of the beach and storm areas, and the other was downstream of the beach area.

The above stations were all sampled daily from July 6 to July 8, and analyzed for fecal coliforms, fecal streptococci, *Pseudomonas aeruginosa*, and *E. coli*, as well as turbidity. Field conductivity and temperature were measured at most locations.

In August 1984, the grid (Figure 2) was modified in order to concentrate sampling effort on the areas of greatest impact, as observed during the July survey. Stations west of the Belleville bridge, including Zwick Island, were deleted, as were the mid-bay and downstream bay locations. Several additional nearshore and bay-mouth locations were added, plus the Belleville STP effluent. In addition, several storm sewers were sampled sequentially on August 14, in order to provide more detailed time-series information on flow and bacterial water quality during an intense rainfall which began at 1420h. On August 15 and 16, all source locations were sampled twice daily to increase overall loading precision; all bay locations were sampled daily from August 14 to 16. All samples were analyzed for fecal coliforms only. Survey dates and rainfall measured at the Belleville WTP are summarized in Table 1.

4.2 1985

As the result of the 1984 surveys indicated that the major source of contamination to the bay originated in the Moira River, the emphasis of the 1985 survey was shifted to involve the gathering of detailed information on the bacterial contamination in the river.

(a) Bay stations: Only a few stations close to shore were sampled, in order to allow some extent of comparison with 1981 and 1984 results. Locations are shown in Figure 3.

(b) Storm sewer outfalls: City of Belleville sewer plans were consulted and the riverbank was surveyed visually so that all potential stormwater sources would be included. A few very small sources (for example, several 6-inch pipes draining single catchbasins on Coleman St.) were eliminated, and the remainder included in the survey. A brief description of the locations of each sewer is given in Table 2, and the locations are shown in Figure 3.

(c) Beach locations. The same four locations at Riverside Beach used in 1984 were again sampled. Zwick Island was not sampled.

(d) River transects: A series of eight transects (3 stations each) were situated throughout the portion of the river in the city (south of highway 401). The purpose of these transects was to determine in better detail the longitudinal distribution of river bacterial contamination. The location of each transect is briefly described in Table 3. Figure 3 also shows location of river transects.

Five additional river transects were located in the watershed within 15 km north of the city limits, plus the Corby Distillers Ltd. outfall which discharges to the river (Figure 4). The purpose of these locations was to determine the source of high bacterial concentrations observed north of Highway 401 during the August 1984 survey.

For purposes of easy identification, each transect surveyed in 1985 was assigned a letter identification, starting at the upstream end. Figures 3 and 4 provide this identification, along with the station numbers.

(e) Sequential sampling: To provide an improved estimate of bacterial loadings at Riverside Beach during wet weather, a sequential sampling survey was performed on July 31 to August 2, 1985. At the start of rainfall, samples were collected at a rate of 2 to 4 per hour from the two storm sewers (15-12 and 15-24; Figure 3) directly above the beach, plus a ditch (15-83) draining parkland in the vicinity of two outhouses. Hourly sampling was also conducted at the four beach locations and a transect immediately upstream of the sewers. On August 1 and 2, only the beach and transect locations were sampled, plus duplicate samples on the morning of August 1 from each source location. Sampling was performed for 4 to 6 hours on each survey day.

Both wet and dry weather sampling were undertaken in 1985. The sampling dates, together with rainfall observed at the Belleville WTP, are summarized in Table 1, which also indicates the number of samples collected daily per station in each component of the survey grid. All samples were analyzed for fecal coliforms and fecal streptococcus. One sample of each duplicate pair and all single samples were analyzed for *E. coli*. All analyses in 1985 were performed at the mobile bacteriological laboratory, situated in Kingston.

5.0 RESULTS

5.1 Receiving Water

5.1.1 1984

Areas in which the single sample fecal coliform count exceeded 100 organisms/100 mL are illustrated in Figure 5 for July and Figure 6 for August. It should be emphasized that the Provincial Water Quality Objectives (PWQO) for the protection of body contact recreation of 100 organisms/100 mL should be applied to the geometric mean of a series of samples and that Figures 5 and 6 merely depict single sample levels as a means of illustrating zones of potential impairment. This is the same method used in illustrating impaired zones in the 1981 Bay of Quinte bacteriological report (Griffiths, 1984).

On July 7, the area in which the objective was exceeded extended eastward to the Bakelite plant, but was confined more closely to shore than the maximum observed in 1981 (August 12; Griffiths, 1984). It was also discontinuous in the vicinity of the Belleville STP, possibly reflecting the effect of chlorine in the final STP effluent and/or storm sewer inputs east of the STP. In August, however, fecal contamination extended offshore to distances similar to those observed in 1981. The larger zones of contamination and higher maximum fecal coliform results apparently reflected the larger amount of rainfall, including a rainfall of 54 mm recorded on August 12.

The highest receiving water fecal coliform counts occurred on August 15, with nine samples recording counts of 1000 or more fecal coliforms/100 mL. The distribution of seven of these samples (Figure 6b) suggested bypassing of raw sewage at the Front St. pumping station; however, sewage plant records indicated no bypassing at this time (W. Gallipeau, Belleville STP, pers. comm.).

In July, measurements were also made for fecal streptococcus, Pseudomonas aeruginosa and E. coli. Their maximum extent was also recorded on July 7. Their distributions (Figure 7) were similar to the fecal coliform distribution, although P. aeruginosa did not show as great a decrease in the vicinity of the STP outfall as did the other parameters. At most locations, E. coli accounted for nearly all the fecal coliforms present. The only exception was bayfront storm sewer 05-07, where E. coli accounted for 17 to 44% of the fecal coliform count.

The Aquatic Ecosystems Objectives Committee in 1983 recommended to the Science Advisory Board of the International Joint Commission that the E. coli geometric mean level in receiving waters should not exceed 23 organisms/100 mL for protection of human recreational users of nearshore waters from increased gastrointestinal illness. This zone is shown in Figure 7c by a dotted line. It is only slightly larger than the fecal coliform zone of figure 5b, except that four of the five Zwick Island beach samples plus one nearby bay sample are in this zone. The same committee recommended that no more than 25% of P. aeruginosa analyses be greater than 10/100mL; the zone indicated in Figure 7b shows locations where P. aeruginosa >10/100 mL. However, it should be noted that these zones are regarded as being only approximate, because they are based on the results of single samples at each station, rather than geometric means.

5.1.2 1985

As the emphasis was placed on source and river data during 1985, only a very limited number of samples were obtained from the river mouth and areas immediately next to shore. Data for July 16 (Figure 8a) and August 1 (Figure 9a) represented conditions occurring on the day after rainfall. On both cases, the area of >100 fecal coliforms/100 mL was apparently smaller than the areas of contamination seen in 1984, including part of the river mouth only plus two isolated bayfront locations on July 16 and none on August 1. On August 8 (Figure 9c), much of the bayfront area exhibited a rapid response to rainfall which had occurred only a few hours earlier; results obtained the day after rainfall suggest that these inputs are more transient and wash away faster than the major input from the river.

Receiving water data obtained after several days of dry weather (Figures 8b and 9b) suggest only limited contamination at the upper end of the river mouth and no problem in the bay proper. These results are similar to that of August 20, 1981 (Griffiths, 1984).

5.2 Beaches

5.2.1 1984

Daily geometric means are given in Table 4 for all bacteriological parameters at both Zwick's Island and Riverside Beach. Geometric means of data obtained by the Hastings and Prince Edward Counties Health Unit (L. Ellenton, pers. comm.) are also given; the latter represent nine sampling data at Zwick's Island and 10 at Riverside Beach.

At Zwick's Island, no single samples exceeded 100 fecal coliforms/100 mL; only 3 of the 45 samples obtained by the Health Unit exceeded 100 fecal coliforms/100 mL. As this location did not appear to be severely impacted by the July 1984 runoff, it was not sampled in August 1984 or in 1985. However, the suggested guideline of 23 *E. coli*/100 mL was exceeded on 2 of the 3 daily geometric means obtained during July 1984.

Extensive contamination was found at Riverside Beach during both surveys, with two-thirds of the samples exceeding 100 fecal coliforms/100 mL in July and 100% exceeding this value in August. Daily geometric means ranged from 111 organisms/100 mL on July 7 to 730 on August 16. The value on August 16 may have been partly related to a rainfall that began at about 1250h, as samples collected about 30 min later had considerably higher fecal coliform counts than those collected earlier in the day. A direct impact was also visually noted on July 6, when a sample collected at station 15-14 shortly after a heavy rainfall registered 1020 fecal coliform/100 mL; this location was directly affected by discharge from the Adam Street storm sewer (15-24) as was evidenced by high turbidity water discharging from this sewer

and following the east river shore. Certainly, runoff prior to and during the sampling periods, plus upstream contamination described in section 5.4 contributed to bacteriological contamination observed at Riverside Beach.

The Ministry findings of runoff impact were also substantiated by the Health Unit data. On each of 5 dates, after rainfalls of varying intensity, the geometric mean fecal coliform count exceeded 100/100 mL, while on the other 5 dates (dry weather), the geometric mean fecal coliform count was below 100/100 mL.

5.2.2 1985

Data obtained on July 15, 31 and August 8 (Table 4) represent wet weather conditions, with rainfalls of 20.0, 4.4 and 2.2 mm, respectively (Table 1). Following the heavy rainfall on July 15, the beaches were still impacted on July 16, with a geometric mean of 182 fecal coliform/100 mL; bacterial levels dropped to 89 and 70 fecal coliforms/100 mL under continued dry weather during the next two days. The rainfall on July 31 was light and intermittent throughout the day; it was insufficient to raise the flow at the Adam St. storm sewer significantly (see Section 5.4.2). Hourly sequential samples collected on July 31, August 1 and 2 failed to detect any systematic time-variation of bacterial concentrations; furthermore the occurrence of high bacterial counts at any one of the four beach locations in this period did not necessarily correlate with the results at the other beach locations.

After this period, no rain fell until August 8, when 2.2 mm of rain was recorded at the Belleville water works, and all 8 beach samples were well above 100 fecal coliforms/100 mL, with a geometric mean of 690 fecal coliforms/100 mL. Apparently, the long antecedent dry period allowed a buildup of high bacterial levels. No storm sewer input data were collected on this day.

Collection of samples by the Health Unit was less regular in 1985 and generally involved only one location on each side of the river at Riverside Beach, and two locations at Zwick's Island. For the most part, high bacterial counts at Riverside Beach were associated with rainfall; however, occasional dry weather high values were also obtained. This was also true with Ministry data on July 30 (Table 4), and indicates the pressure of occasional dry weather inputs or upstream impact (sections 5.3.2 and 5.4.2).

5.3 Storm sewers

5.3.1 1984

In 1984, sampling of sewers draining directly to the Bay was emphasized, and only a few river sewers were sampled. Figures 10-13 inclusive give the daily single sample bacterial counts and Figure 14 the flow rates for the storm sewers and river transects in July 1984. Daily geometric mean fecal coliform results for August 1984 are given in Figure 15, and mean flow rates in Figure 16.

With the exception of 05-05, all Bayfront storm sewers existed as ditches, in which flow rates were difficult to measure, and in some cases, experienced variable in and out flow apparently affected by bay water levels. Except for immediately after the July 6 rainfall, flows were small or non-existent at all Bayfront locations except 05-08 and 05-03. However, location 05-09 exhibited a flow of 17.7 x 10^3 L/min at 1500h on July 6, immediately after heavy rainfall. This was accompanied by a fecal coliform count of 100,000/100 mL and a *Pseudomonas aeruginosa* count of 2900/100 mL. Therefore, although location 05-08 appeared to be the most important continuous bacterial input along the Bayfront, the data showed that other locations such as 05-09 could become important under heavy runoff. High bacterial counts observed at several Bayfront locations on August 14 were accompanied by low flows, and presumably reflected a rainfall that had occurred the previous night (7.4 mm; Table 1). Thus these sewers can be expected to give high bacterial loadings to the Bay for only relatively brief time intervals. High bacterial counts in the Belleville STP effuent in August suggested that the STP was a far more important contributor to bay pollution than the Bayfront storm sewers during the August 1984 event.

West of the river mouth, only very low bacterial loadings and no impact on the receiving water was obseved in July 1984. Except for a location at which spring flooding problems were experienced (Section 5.3.2(c)), these locations were not further studied.

During an August 14 rainfall, sequential samples were taken at river storm sewers 15-12 (just south of Highway 401), 15-24 (Adam St.) and 15-20 (College St.). The results of these sequential samples, plus turbidity measurements and flow estimates, are given in Figures 17-19. Note that the horizontal (time) axis is not to scale in these figures. For this event, peak flows, fecal coliform counts and turbidities roughly coincided, although the exact duration of peak flow was not known. Sewer 15-24 exhibited average flows of about 20 times that of sewer 15-20 and 200 times that of sewer 15-12; as the relative fecal coliform level at 15-20 was about 3 times as high as that of 15-24, the bacterial loading was thus by far the highest at sewer 15-24. This is important as this sewer is located immediately north of the east Riverside beach area.

Single samples were obtained late in the afternoon of the same day at three other storm sewers discharging to the Moira River: 15-23, 15-21, and 15-22. The results (Figure 13) show that all three possess fecal coliform loadings at least as great as station 15-20 mentioned above, and probably higher as they were measured after peak flows had passed. Sewer 15-22, beside the Catharine St. footbridge, is of particular concern, as it recorded 130,000 fecal coliforms/100 mL; its fenced location precluded a quantitative flow measurement. All three locations exhibited a considerable drop in bacterial counts on later days of the survey (and also in July); sewer 15-22 dried up completely and flow at the other sewers dropped to very low levels.

5.3.2 <u>1985</u>

As the 1984 results indicated that the Moira River was the major source of bacteriological degradation of the Bay of Quinte, sampling

in 1985 emphasized all known sewers discharging into the river. A few samples taken in the marshy areas just west of the Bakelite plant in an attempt to determine the reason for high bacterial counts observed in the small embayment immediately west of the Bakelite plant (e.g. July 7, 1984) failed to locate any significant source and are not further discussed.

(a) Dry weather data

Table 4 gives descriptions and dry weather flow estimates of the various sewers. Only qualitative flow estimates were available. Most sewers were either dry or have slight trickles or stagnant water in the manhole chamber or at river level. Sewers with significant dry weather flow include the following: 15-42 (west side at CN tracks), 15-28 (Byron St. at dam), 15-31 (Church St.), 15-32 (Pinnacle St.), and 15-33 (submerged at east side, Bridge St.). The latter sewer had a strong odor of sewage when the manhole was opened on one occasion.

Figures 20-22 show dry weather bacteriological data for the river area storm sewers. Sampling was attempted each scheduled survey day except where the sewer was completely dry; however, a few samples were lost due to breakage or labelling problems. The highest quantified fecal coliform count was station 15-42 on July 30 (2.7×10^6 organisms/100 mL); this location showed consistently high bacterial counts and flow, and appeared to be the most important dry weather bacteriological source. Stations 15-31, 15-32 and 15-33 were also found to be important dry weather sources, but these locations exhibited highly variable bacterial counts. Of the flowing sewers, only 15-28 exhibited consistently low bacteriological counts. Although numerous high bacteriological counts were found, the other locations exhibited flow rates too low to produce significant dry weather inputs. These locations could produce significant first flush inputs at the start of runoff events, however.

(b) Wet weather data

Two types of wet weather data were collected in 1985; duplicate pairs from every sewer during and after a short, heavy rainfall on July 15, and sequential samples from sewers upstream of Riverside Beach on July 31.

Figure 23 shows July 15 bacteriological data, along with times of collection. Sewer sampling began at 1405h (station 15-40) under peak rainfall conditions (most of the 20mm of rain fell within a 2 hour period, approximately 1230 - 1430h, with lighter rainfall lasting until 1605h). As the sewer data represent different points on the runoff pollutographs, they are of limited value in assessing the most significant sources of runoff pollution, however, same observations may be made from the sewer results plus the accompanying transect data. These are discussed in section 5.4.2.

On July 31, sequential sampling was commenced at locations 15-12, 24 and 83 upstream of Riverside Park at 1130h, shortly after rainfall began. Only a light to moderate drizzle occurred, however, and no significant rise in flow rate at any of the three locations was detected. Fecal coliform vs. time results (Figure 24) showed no strong peaks, indicating that the rainfall was insufficient to produce a significant response. (Compare station 15-24 results with the 1984 peak of 2 x 10^4 FC/100 mL shown on Figure 19).

In most of the samples obtained from these three locations, E. coli made up 100% of the fecal coliforms found, or close to that value.

(c) Palmer Rd. sewer

Table 6 gives daily geometric mean bacterial counts for the days of sampling (dry weather) at the Palmer Rd. storm sewer, location of flooding problems under heavy runoffs. The sewer is characterized by tremendous variations in the levels of all three parameters, as well as changes in interparameter ratios. On July 18, three days after a major rainfall, the highest fecal coliform count (18,000 organisms/100 mL) was nearly all *E. coli*, and was accompanied by a FC/FS ratio = 170. But on the other two dates, fecal coliform counts were 230-390 organisms/100 mL, FC/FS ratios <1 and *E. coli* was only 9 to 40% of the fecal coliform count. These results suggest a rapid input of fecal bacteria followed by either die-off or a continuing smaller input of bacteria of largely non-human origin.

Further characterization of the bacterial quality of this storm sewer was done in fall 1985 by Gore and Storrie Ltd. under contract to the City of Belleville.

5.4 River Transects

5.4.1 1984

In 1984, the only river transects sampled were 05-09,10,11 (north of Highway 401), and 05-17,18,19 (south of Riverside Beach) (Figures 1 and 2). Three single midriver sampling stations were sampled in August (Figure 2). Results for three locations are given in Figures 10-13 (July) and 15 (August).

On July 6 and 7, 1984, the fecal coliform geometric means at the downstream transect were 90 and 97 counts/100 mL, showing the effect of inputs from the July 6 runoff. On August 15 and 16, runoff-related fecal coliform geometric means were 327 and 177 counts, respectively. However, during August, geometric means of all samples collected from north of Highway 401 exceeded the Objective of 100 fecal coliforms/100 mL, with values of 579, 277 and 480 fecal coliforms/100 mL on the three days. This coincided with river flows which remained above July values

during the 3-day period. Consequently, the 1985 sampling program included transects located further to the north, in order to locate the source of these high bacterial counts.

5.4.2 1985

Additional transects were sampled in the downstream area in 1985, in order to help to locate the areas with greatest contributions to the high bacterial counts observed during 1984 in the river mouth area of the Bay.

(a) Dry weather data

Figures 20-22 give bacterial counts observed during four days of dry weather sampling in 1985. "Dry weather" includes all data obtained two or more days after the most recent rainfall. Results of July 17, 1985 (exactly two days after rainfall) are similar to those on other included dates. These data are summarized in Table 7 as geometric mean, minimum and maximum counts. The highest geometric mean fecal coliform counts were found at transects K and L just north of the central downstream area, and transect N at the Dundas St. Bridge. These transects are immediately downstream of sewer #15-42 (Section 5.3.2), and also encompass sewers #15-31 and 15-32, all of which were shown to provide significant dry weather inputs. Sewer #15-33 probably contributed to increased geometric mean and maximum bacterial counts seen at transect N.

From Table 7, it is evident that significant dry weather bacterial inputs also enter the river at most reaches upstream of transect J. Despite the very low observed flow rates and variable fecal coliform counts, it appears that one or more of the sewers in the vicinity of West College St. (15-20, 43 or 44) produce significant dry weather inputs, as bacterial counts increased on every survey

day going from transect H to transect J. Between transects E and G, increased fecal coliform and E. coli counts may have been due to bathers using the Riverside Beach swimming areas, or playing in the river immediately downstream of the dam, a park area which receives quite frequent use. Input from sewers in this area is thought to be minimal, because of extremely low (to stagnant) flow rates observed.

North of transect E, these data are consistent with input from the Corby Distillers Ltd. outfall, as discussed later.

(b) Wet weather data

Figures 25-27 give bacterial counts observed during three days of wet weather sampling, plus one date (July 16) which represents the day after a heavy rainfall. August 1 (day after a light intermittent rainfall) has not been included because of the small rainfall or the previous day. In fact, the July 31 data are very similar to the average dry weather data presented above, with the possible exception of the west side of transect L and the east side of transect N. This suggests the observations made during the sequential sampling on that day (Section 5.3.2) that the rainfall (4.4mm) was insufficient to produce a measureable input in the generally previous areas in the north end. Some small inputs probably occurred from several downstream area sewers (impervious areas) on this date.

On August 8, rainfall (2.2 mm) preceeding the survey was even less. Transect data indicate increases in bacterial count at each reach north of transect J with smaller inputs further downstream (again excepting the east end of transect N which shows a large input). This probably suggests that an uneven geographical distribution of

rainfall has occurred on these two dates (i.e. more rainfall in the northern area of the city on August 8 relative to that of July 31 or to that on both days at the Belleville WTP, where the rain guage is located). Unfortunately, no sewer data were collected on August 8, which would have helped to support this suggestion. The results of these two days only show that each rainfall is unique and different area may show different impacts at different times.

By far the heaviest rainfall within the two years of study occurred on July 15. This resulted in the highest river bacterial levels of any survey day; all samples were far above 100 fecal coliform/100 mL, and many were too high to quantify (above 1500 fecal coliforms/100 mL).

On this date, large increases in bacterial concentration within the river occurred between transects H and J; and between transects K and L. Although most of the data at the lowest three transects are "greater than", a large increase is suggested for the east side of the river between stations 63 and 66. These results suggest that the largest sewer inputs occurred at (a) one or more of 15-20,43, 44; (b) one or more of 15-31,32,40,41; and (c) one or more of 15-33,34,35. Input north of Highway 401 was also indicated by the results of >1500 FC/100 mL at transect E. This latter result is discussed later.

i) 15-20,43,44. Although sampled a couple of hours after rainfall ceased, location 15-20 had the highest fecal coliform count (>1.5 x 10^5 FC/100 mL). 1984 data showed that this sewer was one of the important bacterial sources and these results tend to corroborate this fact.

ii) 15-31,32,40,41. No sample was obtained from 15-31, although it was observed to be flowing quite rapidly. Data from 1532 (14000 FC/100 mL) plus the fact that this location was shown to be a significant dry weather source suggest that this sewer is the most important source in this river reach, but the other sewers cannot be ruled out, either.

iii) 15-33,34,35, and other downstream area sewers. The three mentioned east side sewers were all sampled during the heavy rainfall, and all recorded very fast flows (too fast to measure) and fecal coliform individual sample counts of 23,000 to 70,000 FC/100 mL. All must be regarded as important contribution to runoff pollution. In addition, the west side sewers in the lower river (15-21,39,22,38,37) appear to be important wet weather sources; the lower counts at 15-22 and 37 may be an artifact of the later sampling times at these locations, which was well after the peak rainfall and thus after the probable peak is bacterial concentration. As these are all downstream area sewers draining largely impervious areas (streets, sidewalks, parking areas, rooftops, etc.), they reach peak flows and loads rapidly after a rainfall begins, and subside generally within a few hours of cessation of rainfall. Indeed, these sewers were all either dry or only very low flow under dry conditions. More study is needed to determine accurate estimates of bacterial loading in this area.

(c) Transects north of Highway 401.

Figures 28-30 show results of samples taken on July 19, August 1, 7, and 8, 1985, at Moira River transects north of Highway 401, including the same transect (E) used previously and the Corby Distillers outfall. Results at the Corbyville transect for July 31 are also shown on Figures 25-27.

Except for a very brief rainfall which occurred when Palliser Creek was sampled on July 19, the first three dates represent dry weather conditions and August 8 represents wet weather conditions.

On all sampling dates, it is obvious that the major bacteriological input in this river area is at the Corby Distillers outfall, which recorded fecal coliform counts as high as 5.8×10^5 organisms/100 mL. As well as in-plant wastes, this outfall receives agricultural drainage from areas to the north and east of the plant. Such drainage is the probable source of bacteriological contamination observed in this study, as the distillery operates during winter months only. It is also the probable source of contamination observed during other wet weather surveys at the highway 401 transect (e.g. August 1984, July 15, 1985). Samples should be taken from the drainage ditch at the edge of the Corby property, to confirm this source.

Same elevation of bacterial counts was also observed at Palliser Creek, Foxboro, with levels of 136 and 770 fecal coliforms/100 mL. However, the flow in this creek is very low during the summer months, and very little if any elevation of bacterial counts was found between transects above and below this creek.

On August 8, elevated bacterial counts (93-184 fecal coliforms) were found at the Corbyville transect (D). As counts were low at the next upstream transect (C; Twin Bridges), unknown contamination was entering the river in this reach. The source of this contamination should be found.

6.0 DISCUSSION

The results of the 1984 and 1985 Belleville bacteriological surveys have shown the system to be highly complex, with numerous inputs affecting bacterial quality in both dry and wet conditions. Although contamination is greater under wet weather conditions, most of the Moira River within Belleville city limits exceeds the Provincial Water Quality Objective for body contact recreation of 100 fecal coliform/100 mL even under dry weather conditions. This is important as the urbanized lower river is well used for body contact recreation, not only at the Riverside Beach bathing area, but in other places along the well-accessible, shallow, rocky areas north of the Pinnacle St. bridge. Dry weather sewers identified as possessing significant impacts include 15-42 (west side of CN bridge), 15-31 (Church St.), 15-32 (Pinnacle St.), and 15-33 (submerged at east side, Bridge St.). River transect data also suggests additional inputs in the vicinity of College St. and the Riverside Beach area. North of the city, bacterial input possibly derived from agricultural runoff enters the Moira River at the Corby Distillery outfall.

Under wet weather conditions high bacterial levels are observed at nearly every storm sewer, with maximum fecal coliform counts above 10^5 organisms/100 mL. These levels are typical of values found by Qureshi and Dutka (1979) in several urban stormwater runoffs, and approach the bacterial levels of raw wastewaters. Resultant river bacterial levels are as high as 2×10^4 fecal coliforms/100 mL, thereby indicating a potential health hazard. These waters enter the Bay of Quinte, where fecal coliform levels above 1000/100 mL can be found in the river mouth area and above 100/100 mL along most of the bayshore eastward to the Bakelite plant.

Ice control dams have been proposed at several points in the urban and suburban areas of the river, for purposes of flood control. These may create additional opportunities for body contact recreation at other river areas.

The existence of dry weather flows at several sewers as enumerated, indicates the presence of groundwater recharge or infiltration to the sewers from porous soil layers, or the existence of sanitary inputs from illegal cross-connections or cooling water discharges. The latter may be particularly important at locations like 15-31 or 15-32 where fast flow was observed even during dry conditions.

Consideration should be given to diverting at least the low-flow portion of the above-mentioned sewers to the newly expanded Belleville STP for treatment. Further treatment of excess flows under runoff conditions might be helpful in reducing river bacterial levels.

Without a specialized effort, measurement of bacterial concentrations and loadings under runoff in a complicated multi-source system is extremely difficult. Furthermore, the response of different sewers to the same storm, or of same sewers to different storms can be very different. An example is the Adam St. storm sewer, location 15-12. In August 1984 (Figure 17), a significant rise in flow with peak fecal coliform densities of 2×10^4/100 mL was observed after a rainfall of 7.4 mm (plus 53 mm on previous days). However, on July 31, 1985, a rainfall of 4.4 mm failed to produce a significant increase in flow; the time-variation of fecal coliform levels was irregular and the peak was only 330/100 mL (Figure 24). On the same date, the Catherine St. sewer 15-22 (normally dry in dry weather) was flowing (but no measurements were made). This sewer drains largely impervious downstream areas (streets, parking lots, rooftops, etc.); consequently, it does not need a large rainfall to begin flowing and dries up rapidly after a storm. The Adam St. sewer, on the other hand, drains a more pervious, less built-up area on the edge of the city. The open areas absorb and hold a greater portion of a small rainfall; consequently a larger amount of rain is needed for flows to begin. Furthermore, such a sewer can continue to flow long after rainfall has stopped due to infiltration of water through the ground to the sewer. Thus different sewers in different areas may be expected to

behave differently. Several mathematical models are available for simulating flow hydrographs and pollutographs in storm sewers and receiving waters. Delleur and Dredrou (1980) discuss several which might be useful in the Belleville situation. For a full understanding of the effects of runoff on the Belleville storm sewers, the Moira River and Bay of Quinte, modelling is almost essential.

6.1 Fecal Coliform/Fecal Streptococcus Ratios

Fecal streptococcus results have generally been used in conjunction with fecal coliform data as an indication of the major source (human or animal) of bacterial contamination. It was generally considered that a fecal coliform/fecal streptococcus (FC/FS) ratio above 4.0 suggested human fecal contamination, while a ratio below 0.7 suggested non-human contamination (MOE, 1978; Geldrich, 1976). Ratios between 0.7 and 4.0 were thought to suggest mixed origins of contamination.

However, studies in recent years have indicated that FC/FS ratios are not so easily interpreted. For example, a 1984 MOE study on bacteriological contamination of the Toronto Outer Harbour Aquatic Park by ring-billed gulls showed that in July 1984, high fecal coliform levels and FC/FS ratios above 4 occurred while gulls were nesting. Furthermore, analysis of gull feces showed an FC/FS ratio of 8.1, with some individual ratios as high as 84.7. Results of a recent MOE-sponsored research study, performed by Seyfried and Harris at the University of Toronto showed that various animal groups can indeed have FC/FS ratios similar to that of human feces. Non-human waste sources were divided into three groups on the basis of FC/FS ratios (Table 8). It is seen that, especially for dog, duck and gull fecal matter, FC/FS ratios are much higher than previously thought, and it is thus extremely difficult to interpret waste sources on the basis of FC/FS ratios. In addition, FC/FS ratios can change rapidly with time and are generally useful only quite close to fecal pollution sources. For this reason, no attempt is made to discuss receiving water FC/FS ratios; in other areas, ratios are discussed briefly with respect to this caution.

In July 1984, the highest FC/FS ratio quantified was 26, obtained at station 05-07 under variable flow conditions on July 6. Station 05-08, which was the only bayfront location observed to have a high flow of any duration, showed a FC/FS ratio of 17.5 on July 8; as the FC value on July 6 and 7 was "greater than", the ratio was not quantified on these dates. Moderately high P. aeruginosa counts from this sewer (252 to 400) suggest the possibly of human contamination at this point. This is interesting as this point is located almost directly south of Belleville Hospital. In general, FC/FS ratios at river sewer locations were quite low; these frequently varied with time, often reaching maximum values soon after rainfall.

In 1985, FC/FS ratios showed great temporal variability, perhaps even more than spatial. Figure 31 shows FC/FS ratios obtained during dry weather conditions at sewers and transects. In general, the river transects indicate mixed sources of bacteria. Sewer 15-42 (beside CN bridge) had FC/FS ratios as high as 600; as the FC values on July 17-18 were "greater than", the ratio was not quantified for these days. Several sewers draining the downstream area also had FC/FS ratios between 20 and 125 in August 7 but very low ratios on other days. Perhaps variable die-off rates of bacteria which have spent different lengths of time in the sewers cause these differences.

Figure 32 shows wet weather FC/FS ratios. Again, most data were inconsistent or indicated mixed bacterial sources. On July 15, many of the transect values were "greater than" and ratios could therefore not be quantified; on the other dates, generally only transect samples were taken. The only sewer to indicate a predominately human or type I animal source on July 15 was #15-38 (west side of river, north of Bridge St.). On July 31, the FC/FS ratio at sewer 15-24 varied considerably with time. During the first 2 1/2 hours of sampling the ratio varied from 2.4 to 8.7; later, the ratio dropped as low as 0.5 and remained at approximately 1 near the end of the day. This is suggestive of mixed sources of bacteria, including groups II and III animals, entering at different times. This result indicates how variable with time the ratios can be, and thus the difficulties in their interpretation. Furthermore, the FS data were also found to be more prone to random variability than FC, e.g. within pairs of duplicates or across a transect. Although the wet weather data in the downtown area are suggestive of a larger proportion of human or type I animal input (e.g. July 31, August 8; Figure 32), these results are far from conclusive considering the problems associated with interpreting FC/FS ratios.

7.0 ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of the following staff at MOE Southeastern Region for their assistance: Mr. G. Owen, Dr. A. Ley, Mr. J. Pruner, Mr. J. Bishop, Mr. M. German, Mr. D. Galloway, Mr. G. Skalin (Belleville District Office), plus laboratory and field support staff. Thanks are also extended to Mr. M. Young, Ms. S. Janhurst and Mr. G. Horsnell and support staff of the Water Quality Section, Laboratory Services Branch for their assistance. The assistance of City of Belleville staff who provided sewer plans and assisted in the location and opening of sewer manholes is gratefully acknowledged. The assistance of the Hastings and Prince Edward Counties Health Unit, who provided important beach data, is gratefully acknowledged. Thanks are also extended to Ms. M. Griffiths, Dr. M. Zarull and Mr. F.C. Fleischer of the Great Lakes Section for their helpful comments.

This project was partly funded by Environment Canada under the auspices of the Canada-Ontario Agreement.

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TABLE 1

Survey Dates
Belleville Bacteriological Survey, 1984-85

(a) 1984

Date	Rainfall (mm), 24 hours previous ending at 0900 h
July 6	1.0 (July 5 - 5.0)
July 7	9.4
July 8	nil
August 14	7.4 (August 13 - 9.0; August 12 - 45.0)
August 15	1.8
August 16	nil

(b) 1985

Date	Rainfall (mm) 24 hours	Samples per station*		
		Sewers	River transects	Bay
July 15	20.0	2	2D	-
July 16	nil	-	1D	2
July 17	nil	2	2D	-
July 18	nil	1	1D**	2
July 30	nil	2	2D	1
July 31	4.4	***	2D	-
August 1	nil	***	1U + 1D	2
August 2	nil	***	2U + 2D	1
August 7	nil	2	1U + 1D	2
August 8	2.2	-	2U + 2D	1

NOTE: * U = upstream (Figure 4), D = downstream (Figure 3).
** Plus 1U on July 19.
*** Sequential sampling of Riverside Beach and area sewers.

TABLE 2

1985 Belleville Area Bacteriological Survey
Storm Sewer Sampling Locations

STATION #	DESCRIPTION
15-24	Adam St. SS
15-28	Byron St. SS
15-29	College and Cannifton area SS
15-20	College St. E. and CN yards SS
15-30	Open ditch north of Station St.
15-31	Church St. SS
15-32	Pinnacle St. SS (under bridge)
15-33	E. Side, Bridge St.
15-34	Near 138 Front St.
15-35	Front and Dundas St.
15-36	S. Side of Dundas St., opposite Coleman St.
15-37	W. Side, Bridge St.
15-38	Near 221 Coleman St.
15-22	Catherine St. SS (beside footbridge)
15-39	Near 257 Coleman St.
15-21	Henry St. box sewer
15-40	N. Front St. SS
15-41	Near Moira and Pinnacle St.
15-42	Open ditch, Moira St. at CN tracks
15-43	S. Side College St., west of river
15-44	N. Side College St., west of river
15-23	S. of Riverside Park, west of river.
15-45	Dundas St. W. at Palmer Rd. (special survey)
05-08	Bayfront ditch S. of Macdonald Av.
15-46	Culvert beside waste pond at DeLoro Stellite
05-13	Ditch to bay below DeLoro Stellite
15-47	First culvert east of Farley on CPR
15-48	Second culvert east of Farley on CPR
05-10	Ditch to bay west of Bakelite plant

TABLE 3

1985 Belleville Area Bacteriological Survey
Moira River Transect Locations

Transect Designation	Station Numbers	Location
A	15-76,77,78	Upstream of Highway 37 bridge (O'Brian's Bridge)
B	15-73,74,75	At CN bridge 2 km NE of Foxboro
C	15-70,71,72	Twin Bridges (S. edge of Foxboro)
D	15-67,68,69	At Corby Distillers dam (about 0.5 km upstream of outfall)
E	15-09,10,11	Cannifton (about 1 km north of Hwy 401)
F	15-80,81,82	0.3 km south of Hwy. 401 bridge
G	15-17,18,19	0.2 km north of McFarland Drive
H	15-49,50,51	0.1 km south of Byron St. dam
J	15-52,53,54	0.1 km north of CN bridge
K	15-55,56,57	beside old mill at Dafoe St.
L	15-58,59,60	at river bend (Moira St.)
M	15-61,62,63	0.1 km south of Catharine St. footbridge
N	15-64,65,66	north side of Dundas St. Bridge

TABLE 4

Belleville Beaches Bacteriological Data, 1984-85

	Fecal Coliforms Geom. mean #/100 mL	Fecal Coliforms Fraction >100/100 mL	Fecal Streptococcus	Escherichia Coli	Pseudomonas Aeruginosa
			Geometric means # /100 mL		
Riverside Beach					
1984 July 6	150	3/4	172	134	<2
7	111	3/4	91	97	<2
8	113	2/4	74	112	<1
August 15	420	8/8	-	-	-
16	730	8/8	-	-	-
Health Unit 1984	127	18/40	-	-	-
1985 July 15	120	7/8	92	99	-
16	182	4/4	222	-	-
17	89	1/8	28	88	-
18	70	0/4	62	-	-
30	117	4/8	167	94	-
31	80	3/12	72	78	-
August 1	104	9/24	57	101	-
2	86	7/20	45	85	-
8	690	8/8	315	628	-
Health Unit 1985	88	12/31	-	-	-
Zwick Island					
1984 July 6	30	0/5	64	30	<4
7	50	0/5	53	49	<3
8	11	0/5	10	11	<3
Health Unit 1984	14	3/45	-	-	-
1985	19	3/17	-	-	-

TABLE 5

Storm Sewers Discharging to Moira River Sampled in 1985

Station #	Location	Description	Dry weather flow
(a) West side of river			
15-23	S. of Riverside Park	66" (1.68m) diam. culvert	stagnant water
15-44	N. of College St.	30" (0.76m) diam. culvert	trickle
15-43	S. of College St.	21" (0.53m) diam. culvert	trickle
15-42	N. of CN tracks	open ditch	low to moderate
15-41	beneath bridge at Pinnacle St.	33" (0.84m) diam. culvert	dry
15-40	S. of N. Front St. bridge	27" (0.675m) diam. culvert	dry
15-21	Henry St.	55" x 96" (1.40 x 2.44m) box culvert	dry
15-39	near 257 Coleman St.	30" (0.75m) diam. culvert in river wall	dry
15-22	Catherine St. (beside footbridge)	11 x 18" (0.28 x 0.46m) elliptical culvert	dry
15-38	beside 211 Coleman St.	17" (0.45m) diam. culvert in river wall	dry
15-37	S. side of Bridge St. bridge	opening in wall at river level	standing river water
15-36	S. side Dundas St.	chamber beneath pumphouse	standing river water

TABLE 5 (cont'd)

Station #	Location	Description	Dry weather flow
(b) East side of river			
15-12	S. of Hwy. 401 interchange	culvert beneath Cannifton Rd.; ditch to river	stagnant water
15-24	Adam St.	60" (1.52m) diam. culvert	trickle
15-83	in Riverside Park	small ditch near outhouses	dry
15-28	Byron St. at dam	24" (0.61m) diam. culvert	fast flow
15-29	beside College St.	18" (0.46m) diam. culvert	dry
15-20	south of College St.	twin 72" (1.83m) box sewers	very small trickle
15-30	open ditch north of Station St.	open ditch in grassy area	stagnant
15-31	Church St.	24" (0.61m) diam. culvert	fast flow
15-32	beneath bridge at Pinnacle St.	24" (0.61m) diam. culvert	fast flow
15-33	Bridge St.	42" (1.07m) submerged drain	moderate flow, sewage smell
15-34	near 138 Front St.	24" (0.60m) submerged drain	stagnant water in chamber
15-35	north side Dundas St.	35" (0.90m) submerged drain	stagnant water in chamber

TABLE 6

Palmer Road Sewer (St. 15-45)
Daily Geometric Means, 1985

Date	Fecal Coliforms	Fecal Streptococcus	E. Coli
July 18	18,000	106	16,000
July 30	390	1,250	155
August 7	230	320	20

TABLE 7

Range of Bacterial Counts Observed at River Transects
Belleville, 1985, Dry Weather

Transect	Fecal Coliforms			Fecal Streptococcus			E. coli		
	G.M.	Min.	Max.	G.M.	Min.	Max.	G.M.	Min.	Max.
D (67,68,69)	14	8	42	58	29	364	14	5	42
E (09,10,11)	53	32	101	71	10	1220	59	34	100
G (17,18,19)	91	59	172	70	18	354	96	48	160
H (49,50,51)	100	66	148	95	22	1060	104	74	140
J (52,53,54)	164	86	360	285	98	1640	188	122	304
K (55,56,57)	225	50	350	160	55	452	200	45	335
L (58,59,60)	239	160	385	235	106	1500	244	130	385
M (61,62,63)	180	108	284	310	70	1930	180	108	276
N (64,65,66)	215	95	1590	110	42	339	156	95	250

NOTE: All results in counts / 100 mL.
Data based on July 17, 18, 30 and August 7.
(Transect D - July 19, 30, August 7)

TABLE 8

(FC/FS) Ratios in Warm-Blooded Animal Feces

Fecal Source	Ratio (FC/FS)	Group Number
Human	20+	-
Gull	10+ to 20+	I
Duck	10+ to 20+	I
Dog	10+ to 20+	I
Pigeons		II
Muskrat	About 1	II
Chicken	to	II
Pig	Less Than 5	II
Cat		II
Goose		III
Racoon	Less Than 0.5	III
Cow		III

Source: MOE-Sponsored Research Study - Preliminary Results cited in Humber River Bacteriologial Study, Technical Report #6 (TAWMS).

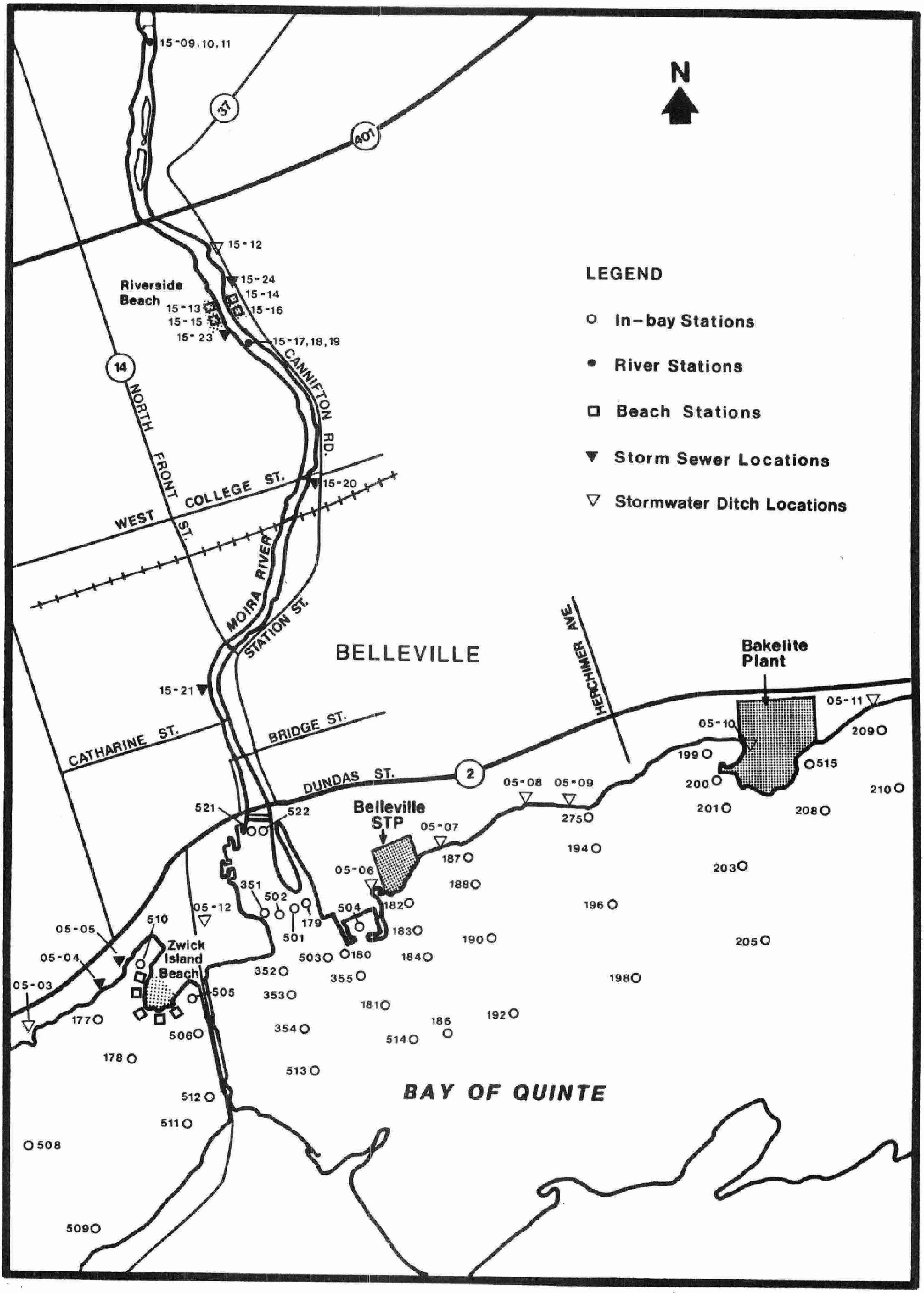


FIGURE 1: SAMPLING STATIONS, BELLEVILLE BACTERIOLOGICAL SURVEY, JULY 1984

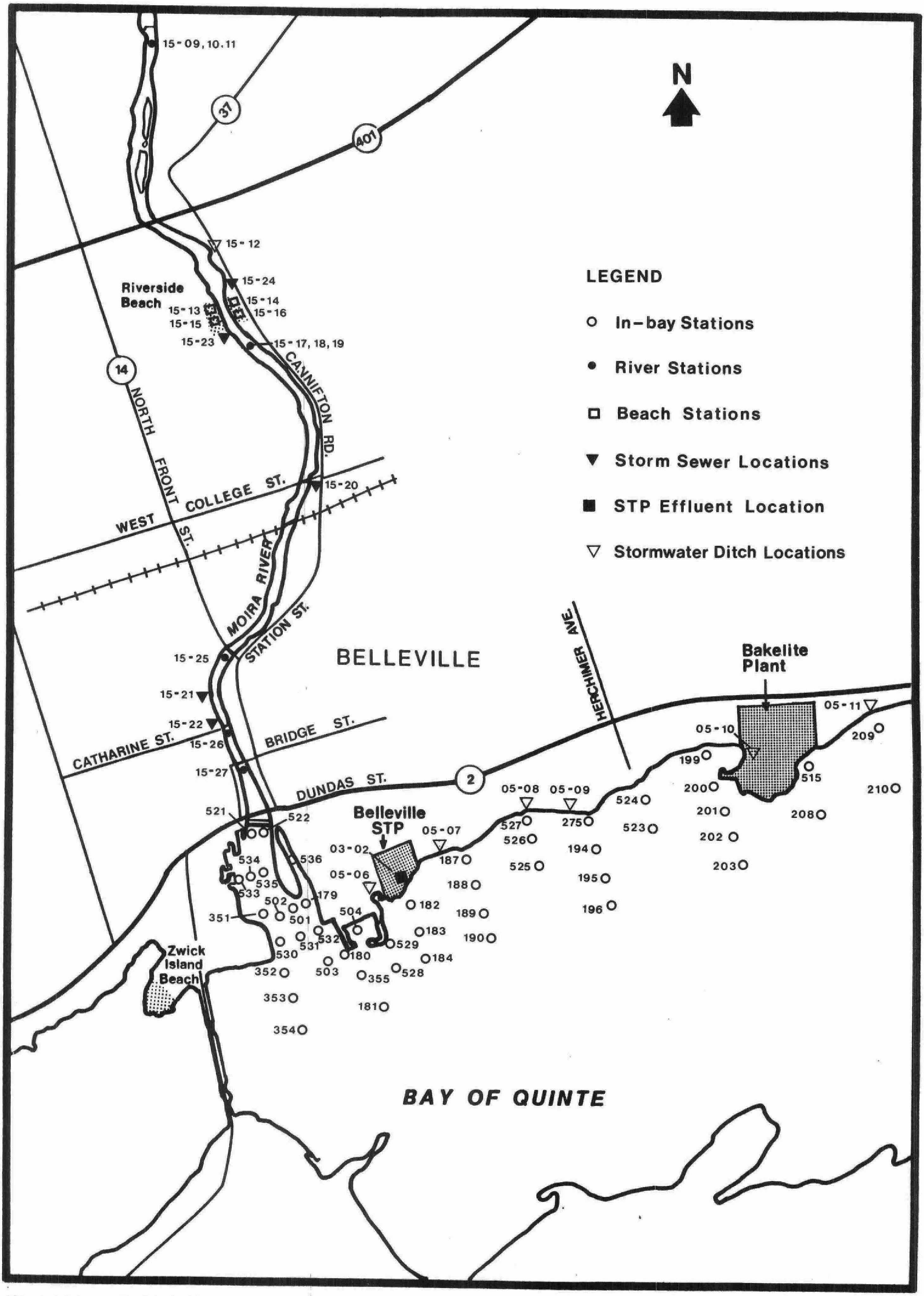


FIGURE 2 : SAMPLING STATIONS, BELLEVILLE BACTERIOLOGICAL SURVEY, AUGUST 1984

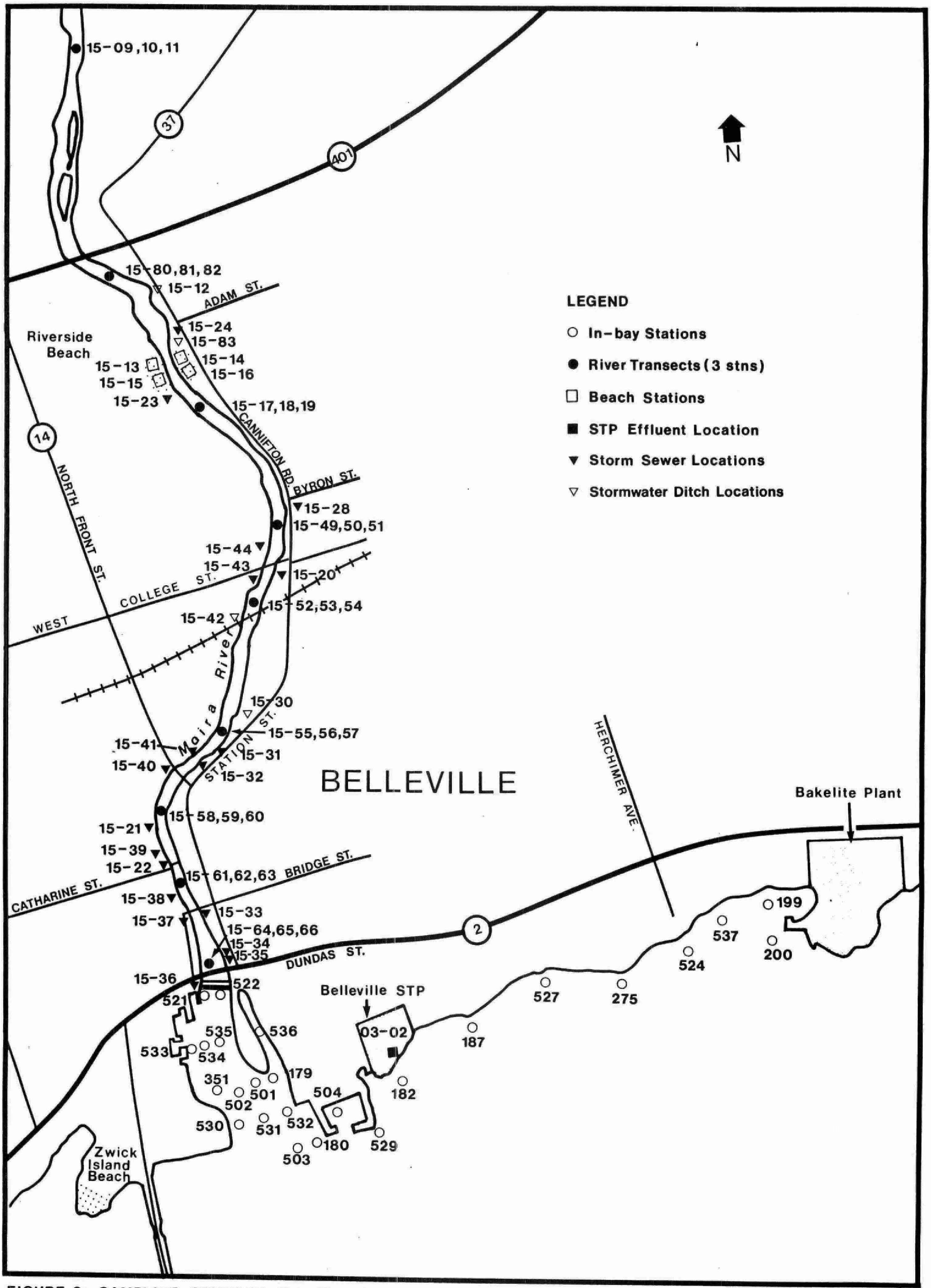


FIGURE 3: SAMPLING STATIONS, BELLEVILLE BACTERIOLOGICAL SURVEY, JULY-AUGUST, 1985

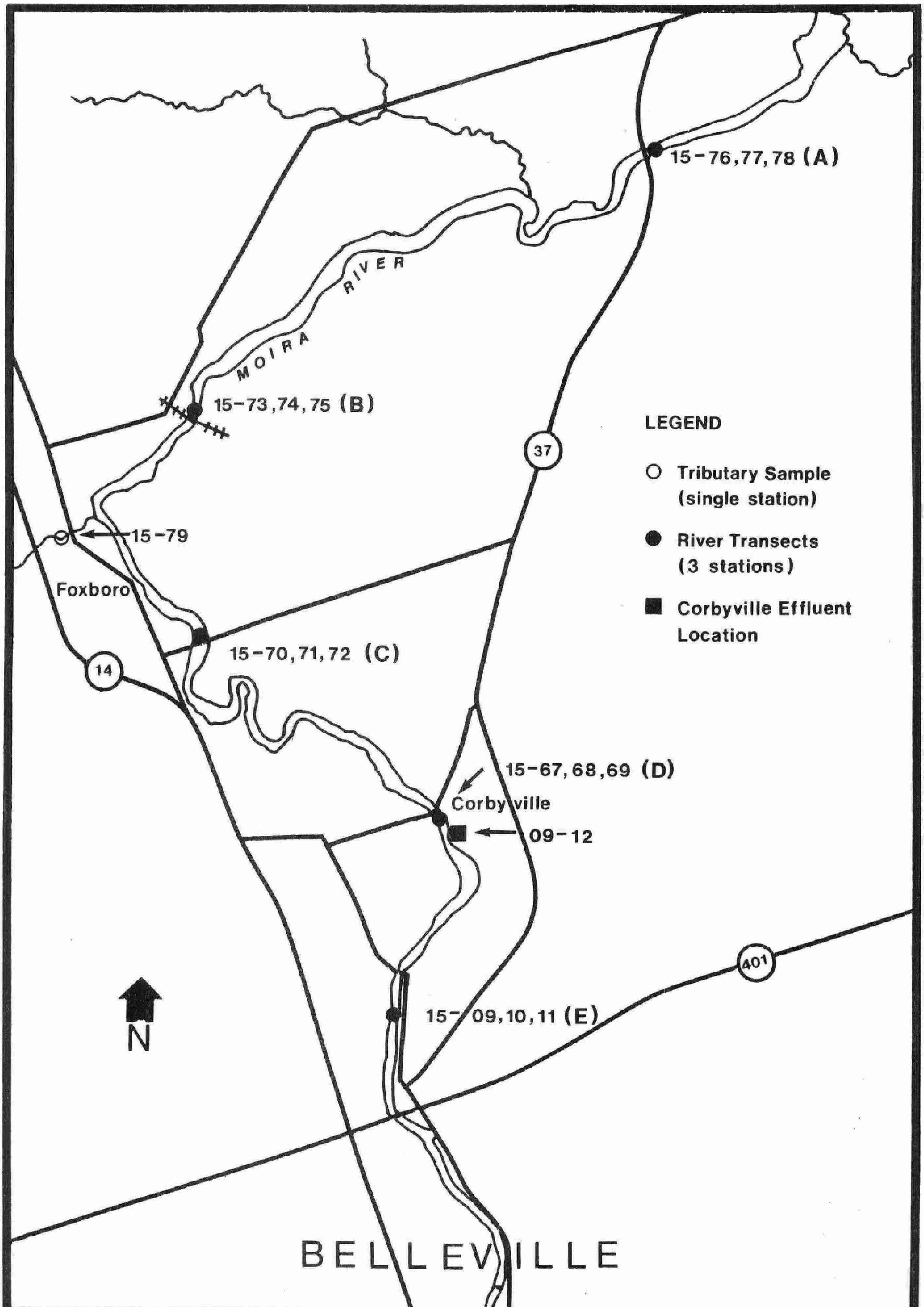


FIGURE 4 : TRANSECTS NORTH OF HIGHWAY 401, BELLEVILLE, 1985

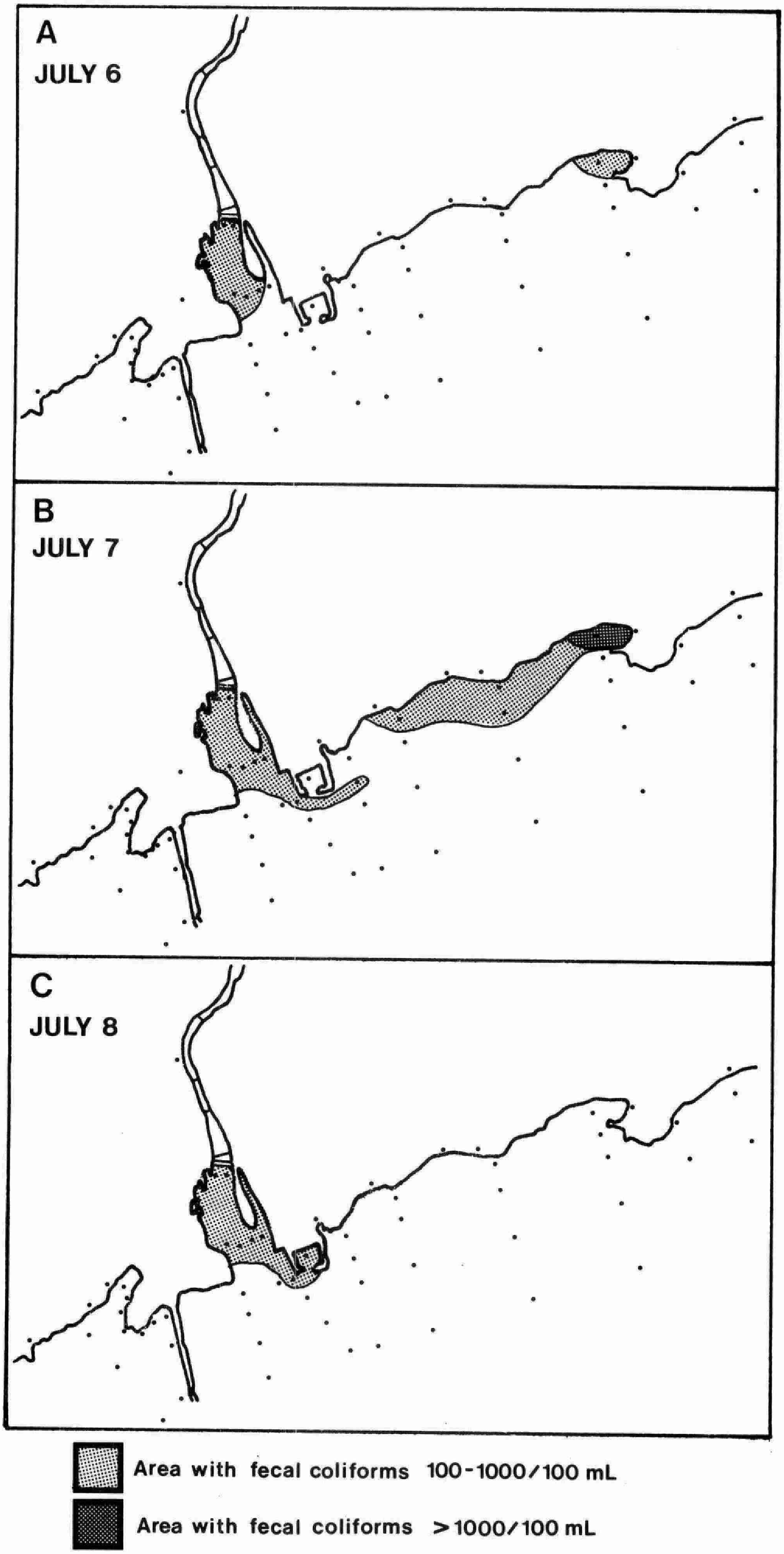


FIGURE 5 : FECAL COLIFORM COUNTS, BELLEVILLE, JULY 1984

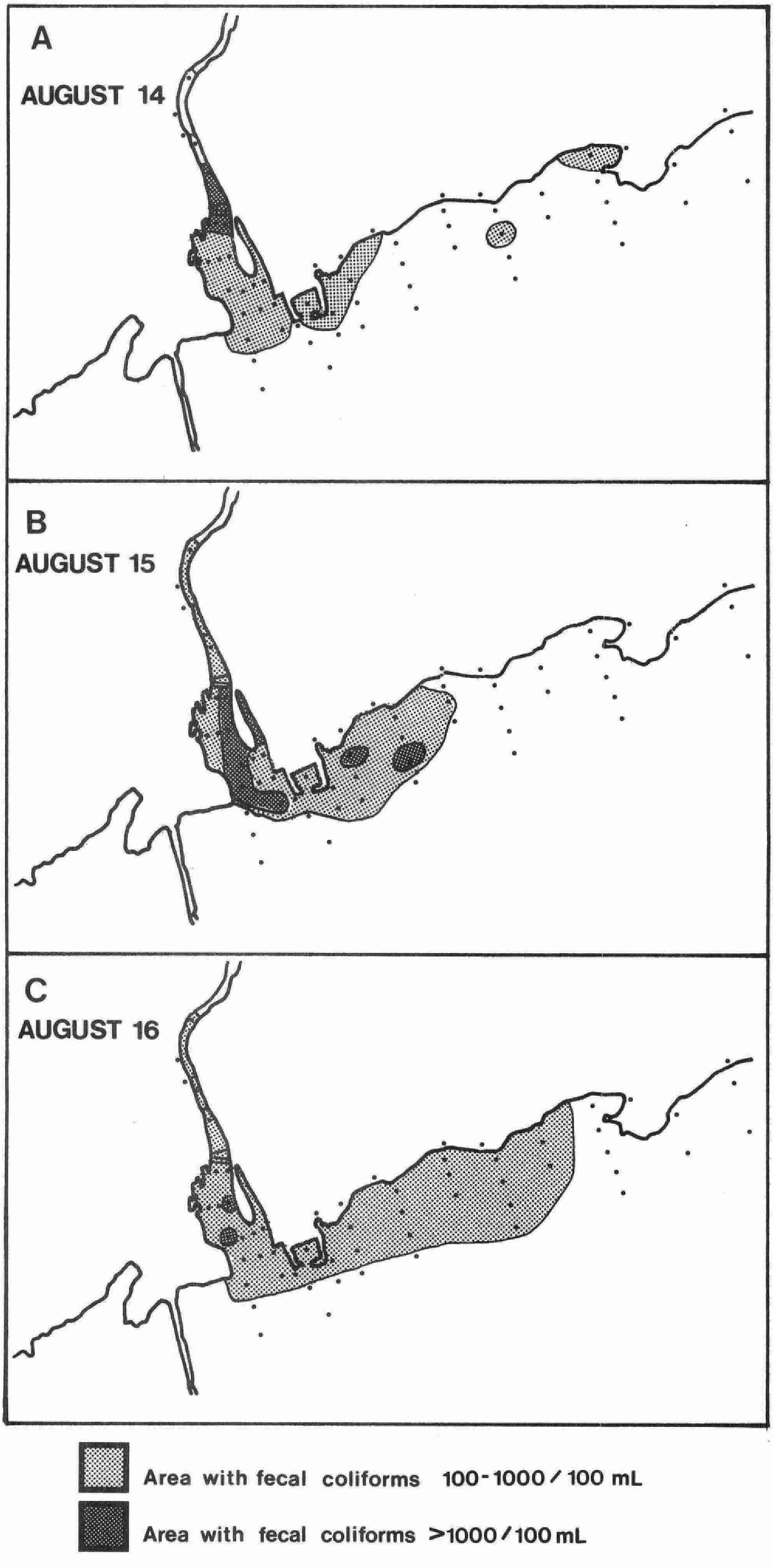


FIGURE 6 : FECAL COLIFORM COUNTS, BELLEVILLE, AUGUST 1984

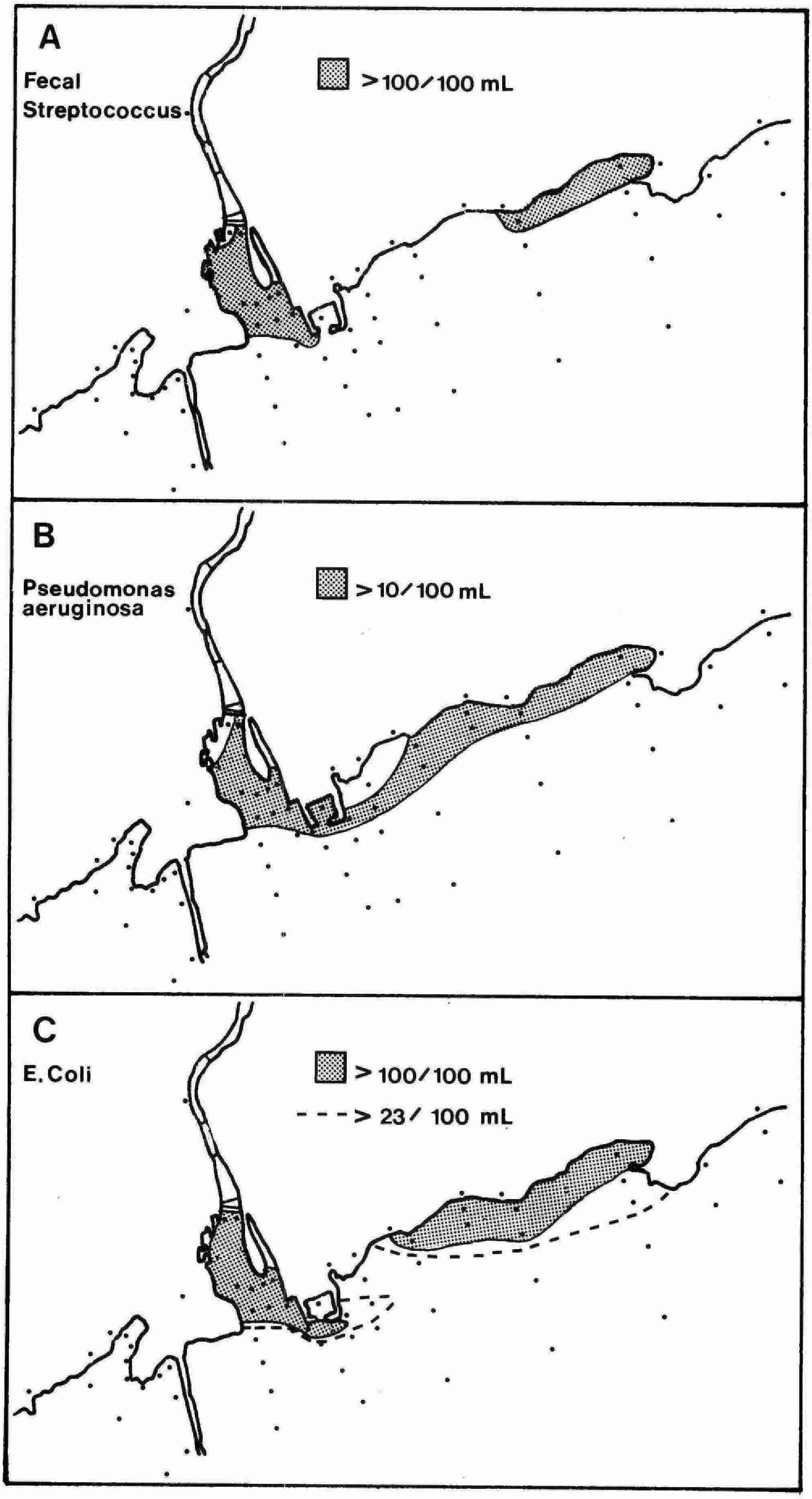


FIGURE 7 : MAXIMUM EXTENT OF OTHER BACTERIOLOGICAL PARAMETERS, BELLEVILLE, JULY 7, 1984

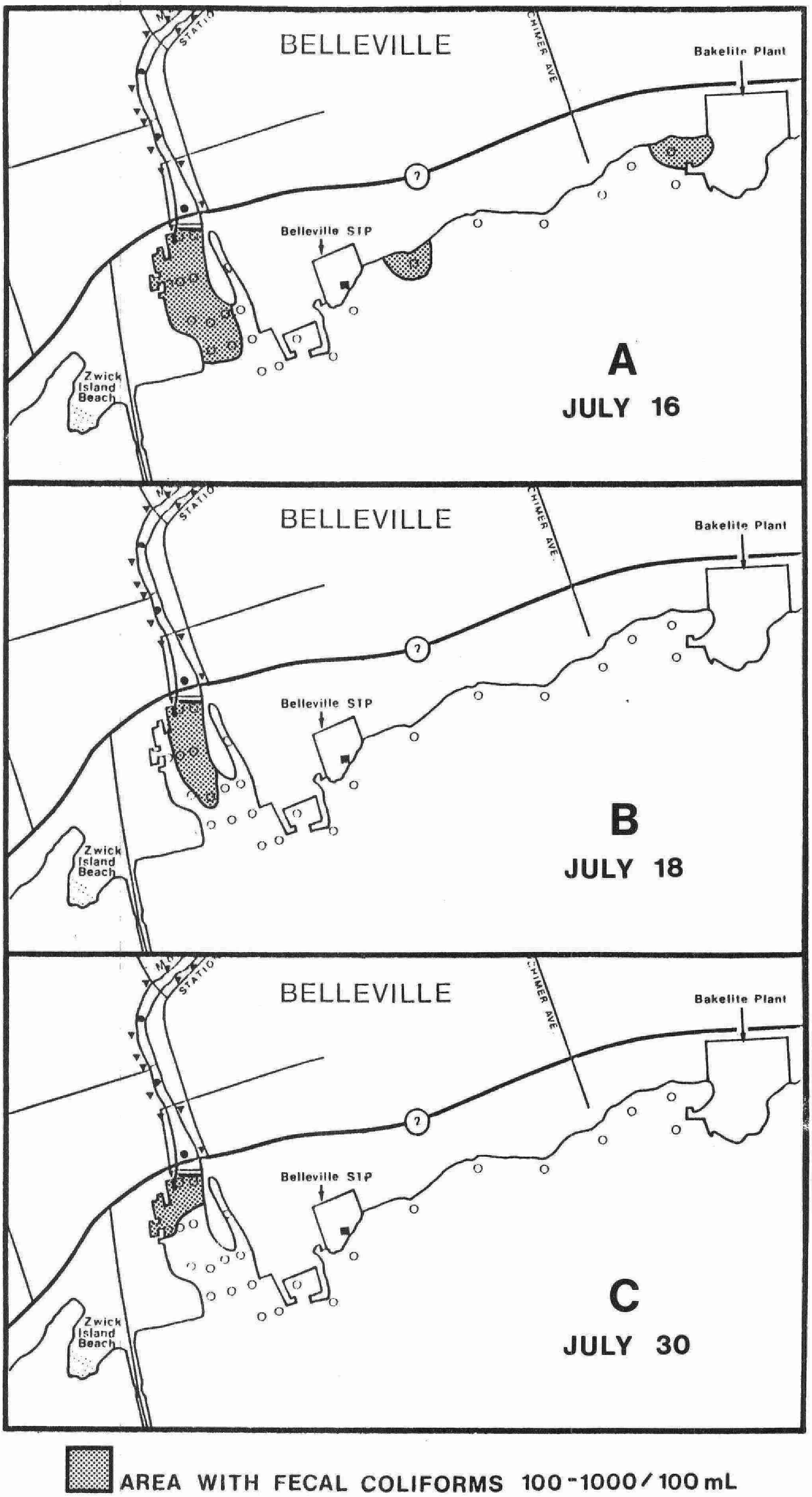


FIGURE 8 : FECAL COLIFORM COUNTS BAY OF QUINTE, AT BELLEVILLE, JULY, 1985

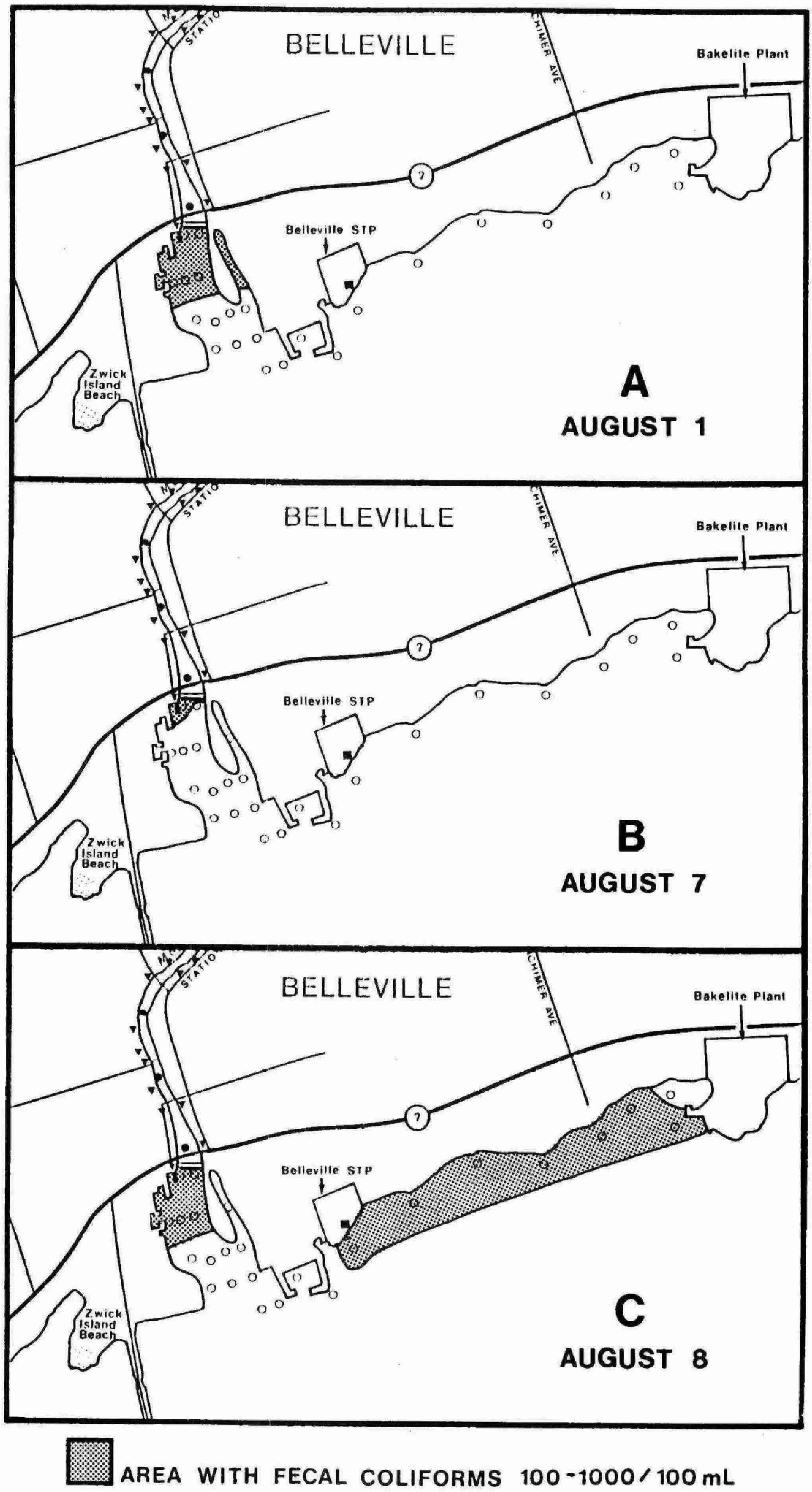


FIGURE 9 : FECAL COLIFORM COUNTS, BAY OF QUINTE AT BELLEVILLE, AUGUST, 1985

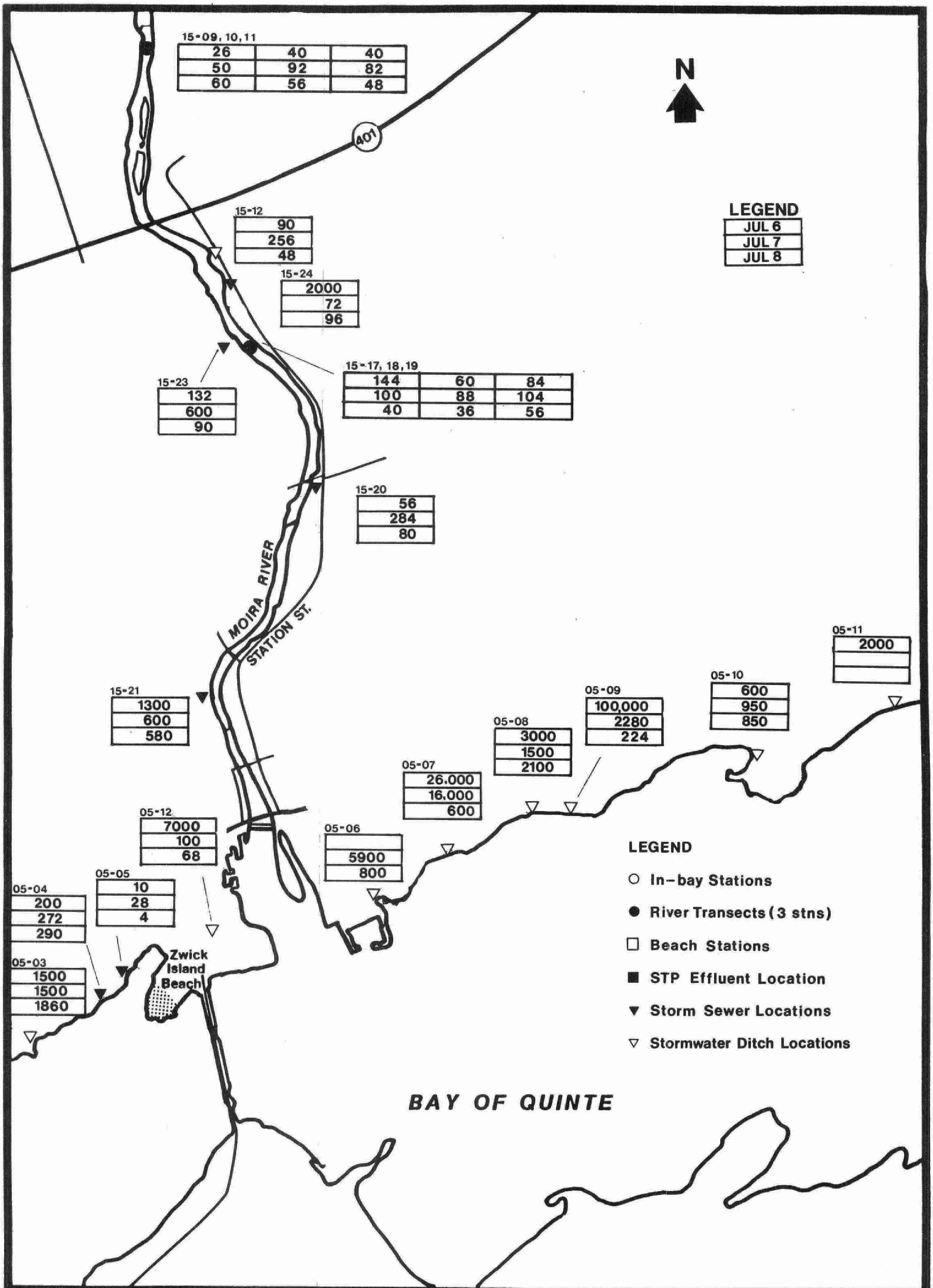


FIGURE 10: FECAL COLIFORMS COUNT/ 100 mL - STORM SEWERS, MOIRA RIVER TRANSECTS, BELLEVILLE, JULY 1984

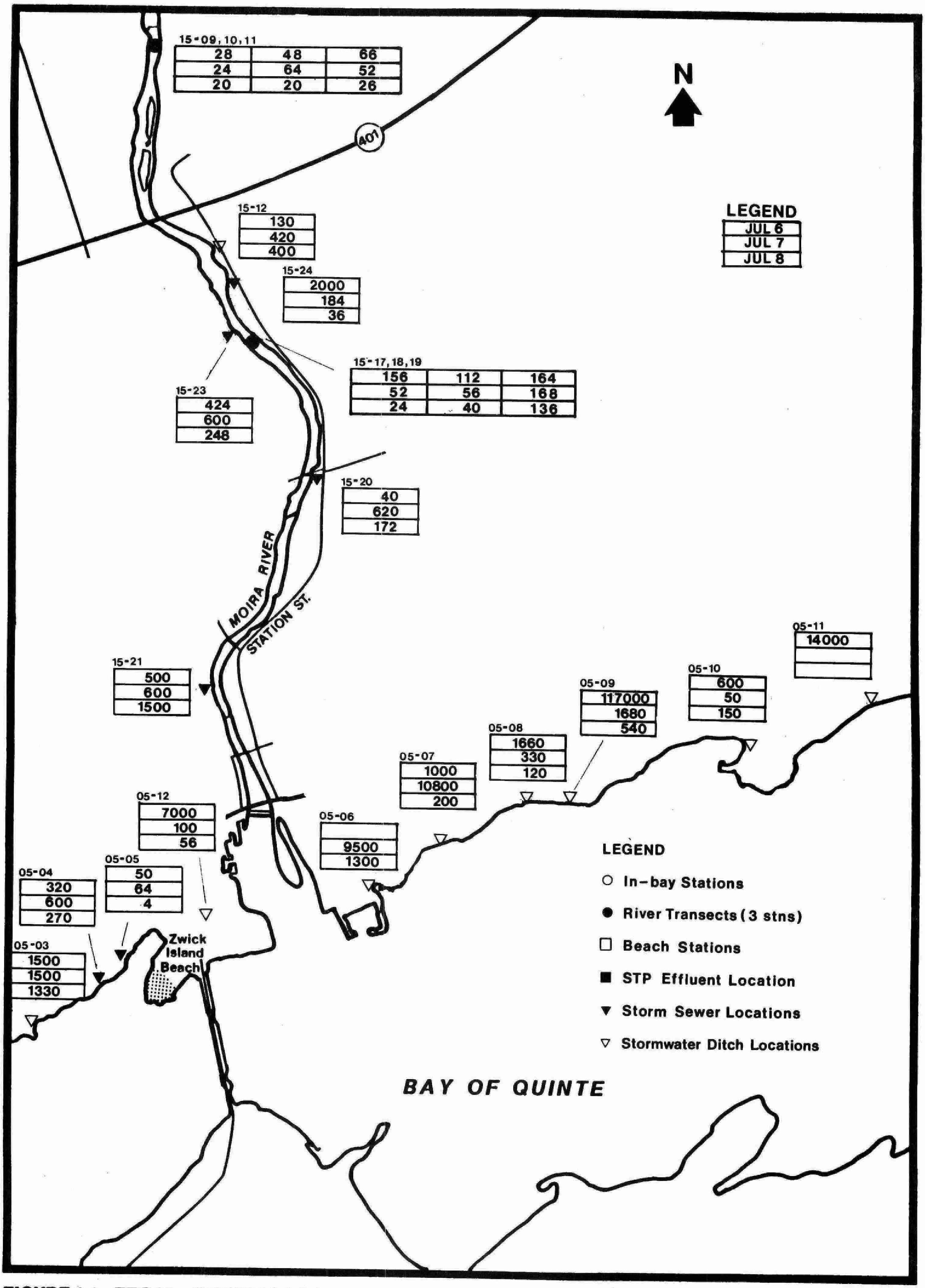


FIGURE 11: FECAL STREPTOCOCCUS COUNT/ 100 mL - STORM SEWERS, MOIRA RIVER TRANSECTS, BELLEVILLE, JULY 1984

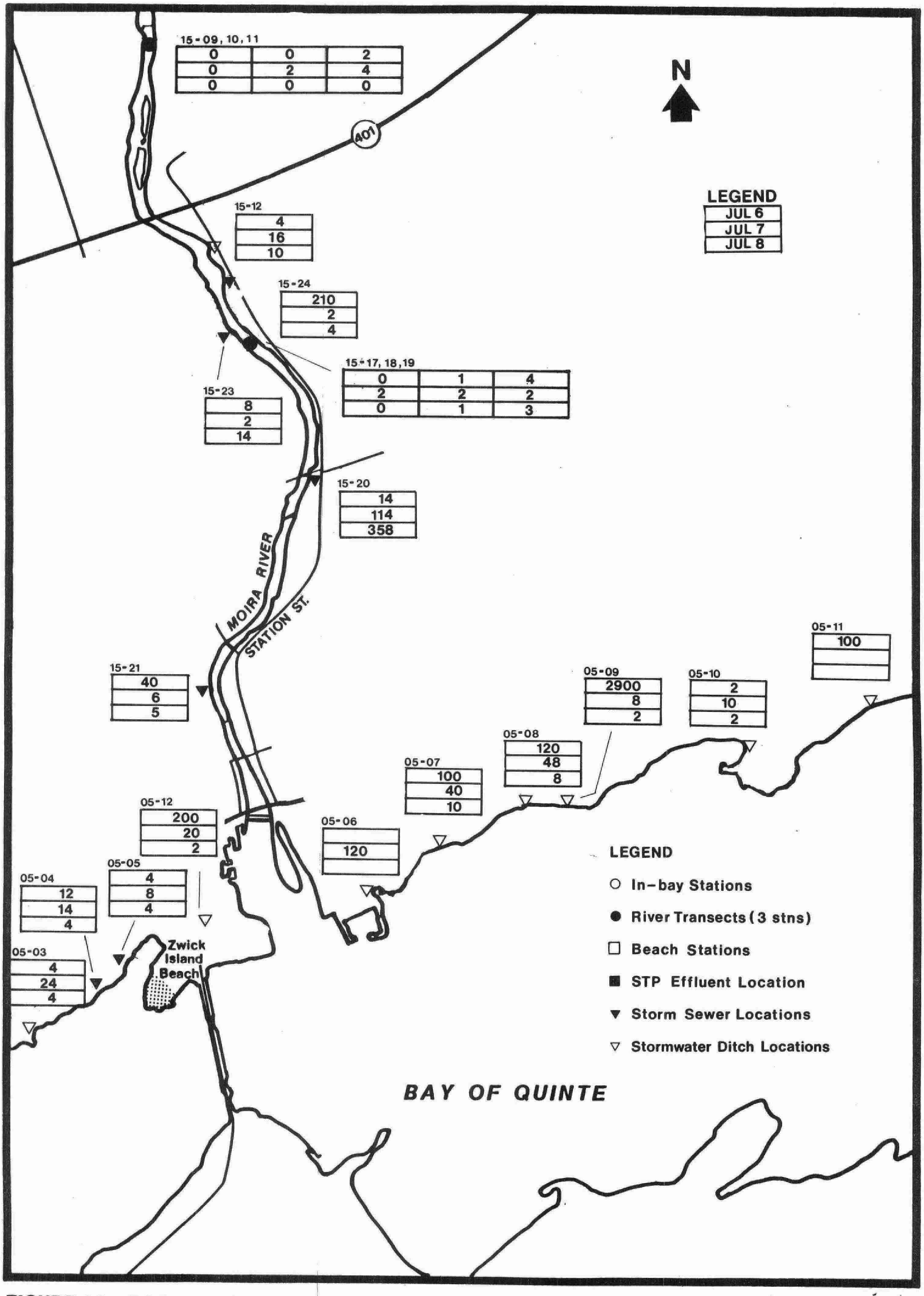


FIGURE 12: PSEUDOMONAS COUNT/100 mL STORM SEWERS, MOIRA RIVER TRANSECTS, BELLEVILLE, JULY 1984

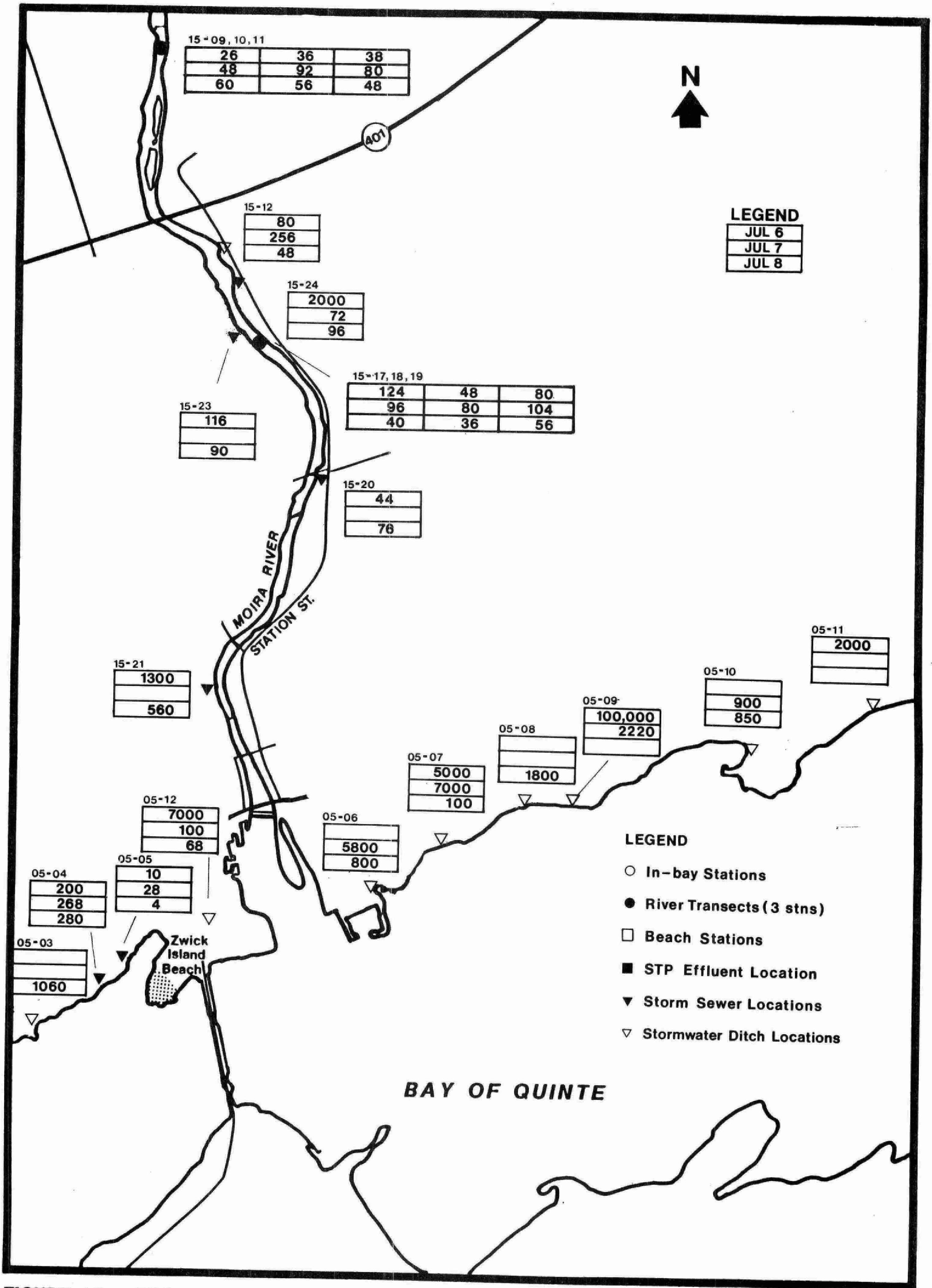


FIGURE 13: ESCHERICHIA COLI COUNT /100 mL STORM SEWERS, MOIRA RIVER TRANSECTS, BELLEVILLE, JULY 1984

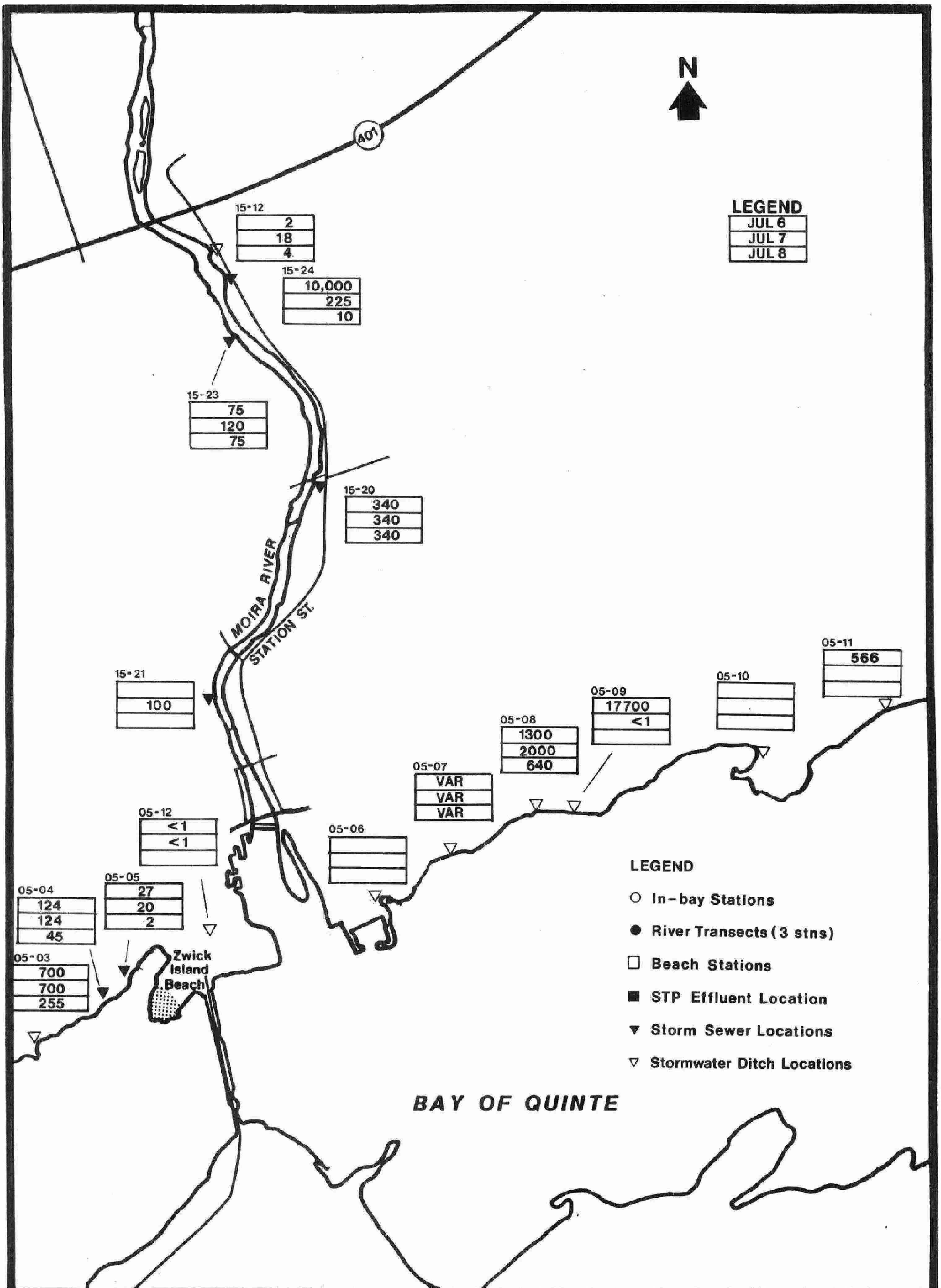


FIGURE 14 : FLOW, L/min STORM SEWERS, BELLEVILLE, JULY 1984

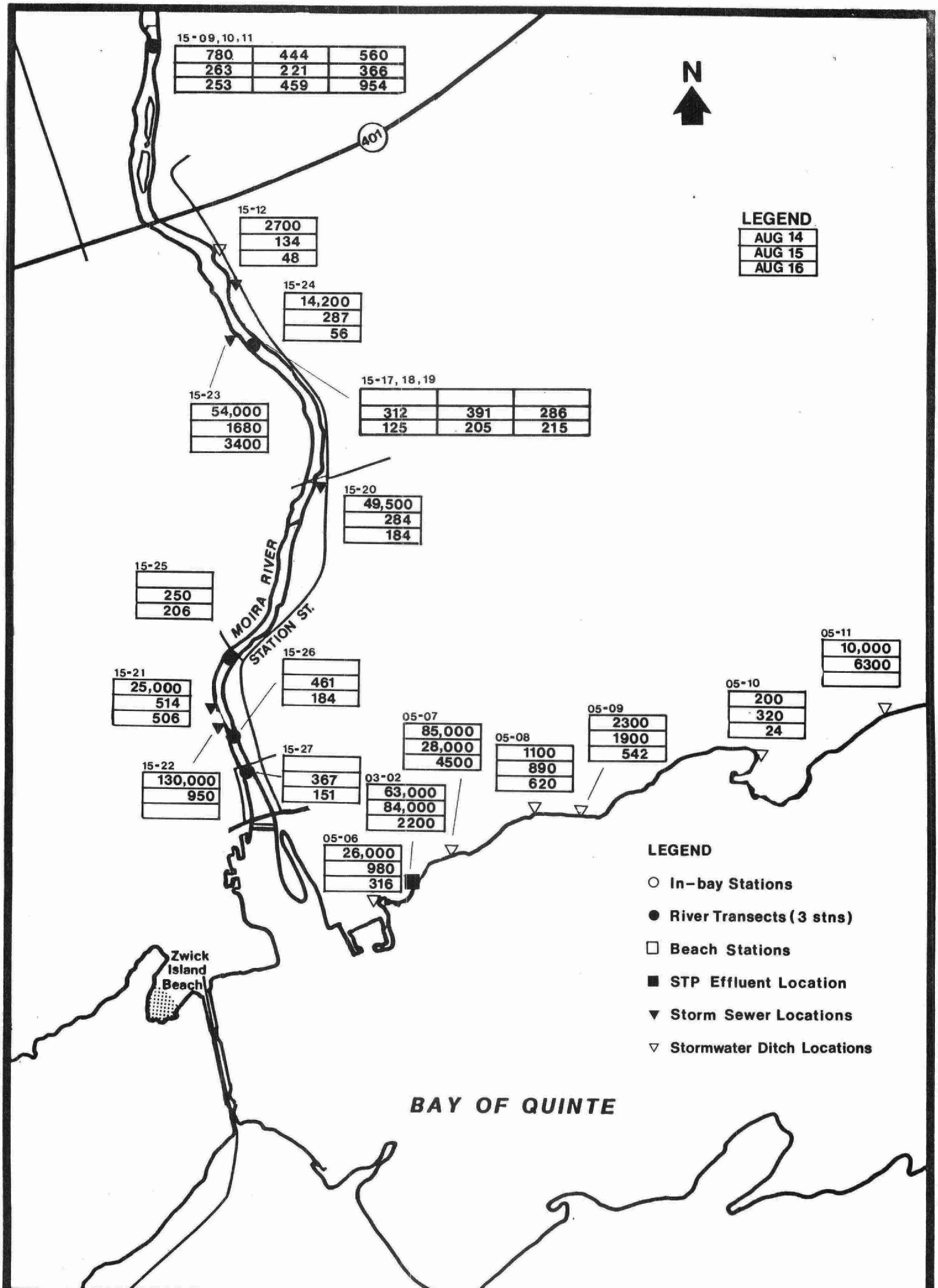


FIGURE 15: FECAL COLIFORMS/ 100 mL STORM SEWERS, MOIRA RIVER TRANSECTS, BELLEVILLE, AUGUST 1984

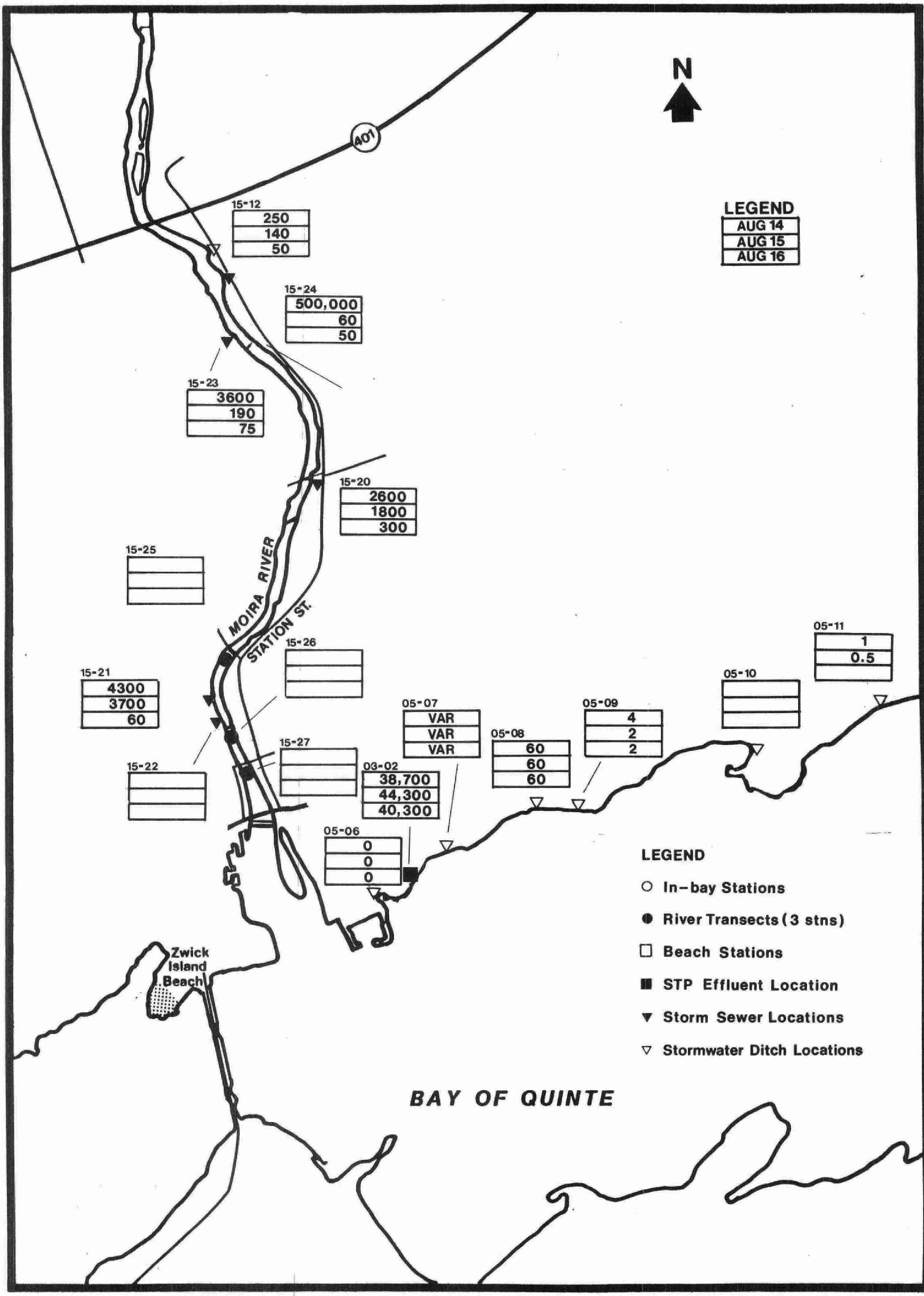


FIGURE 16 : FLOW, L/min STORM SEWERS, BELLEVILLE, AUGUST 1984

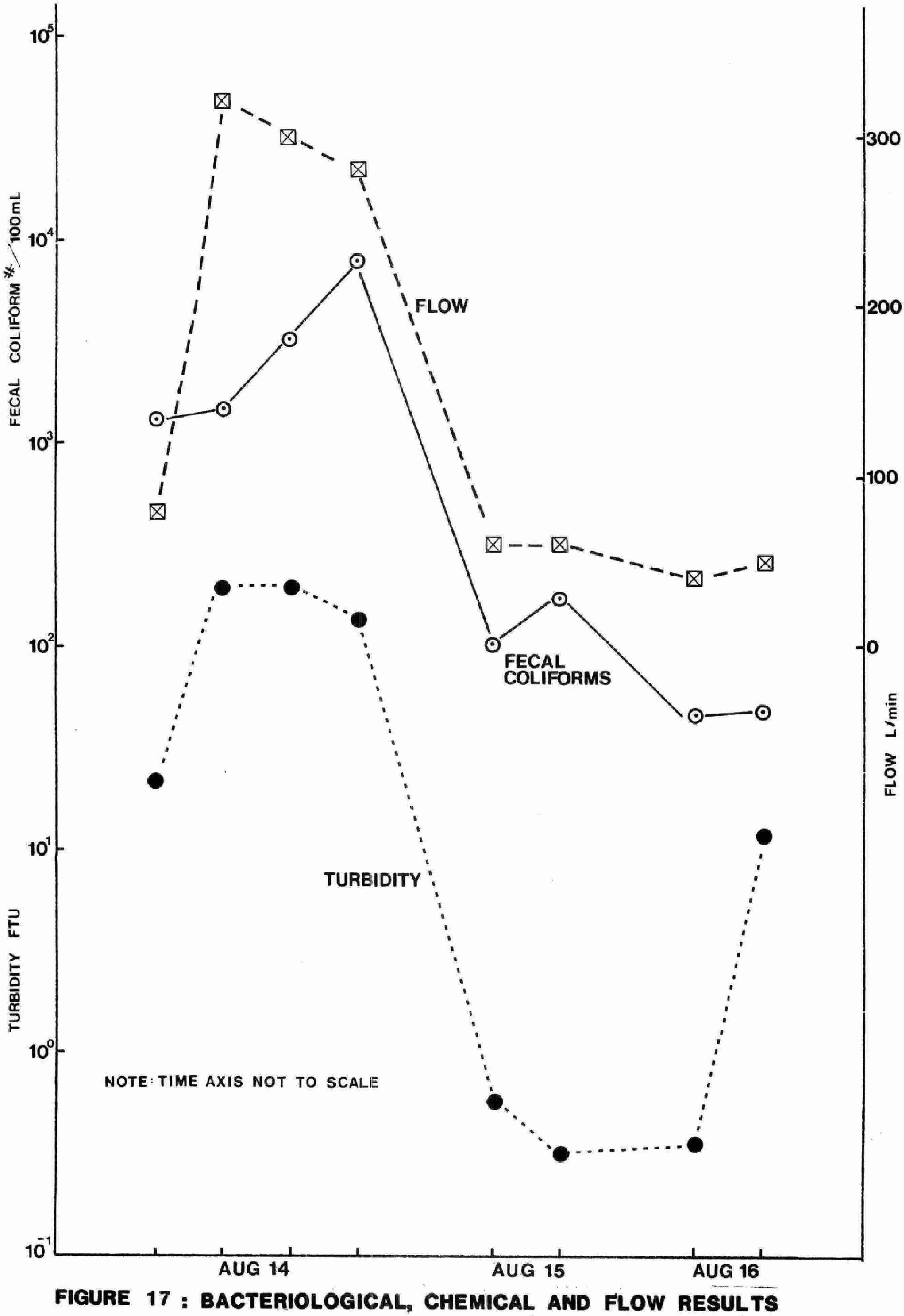


FIGURE 17 : BACTERIOLOGICAL, CHEMICAL AND FLOW RESULTS FOR STATION 15-12, AUGUST 1984

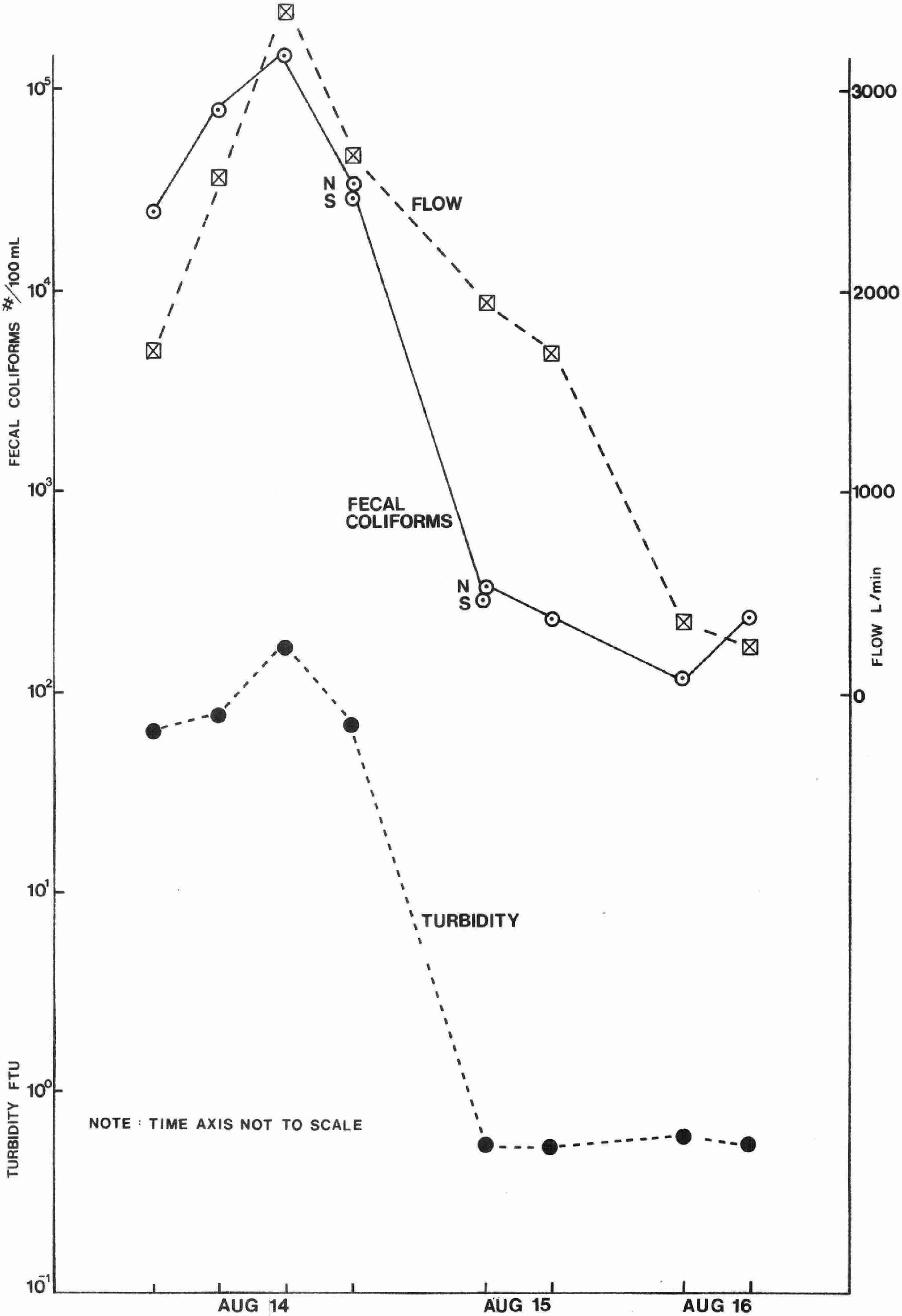


FIGURE 18 : BACTERIOLOGICAL, CHEMICAL AND FLOW RESULTS FOR STATION 15-20, AUGUST 1984

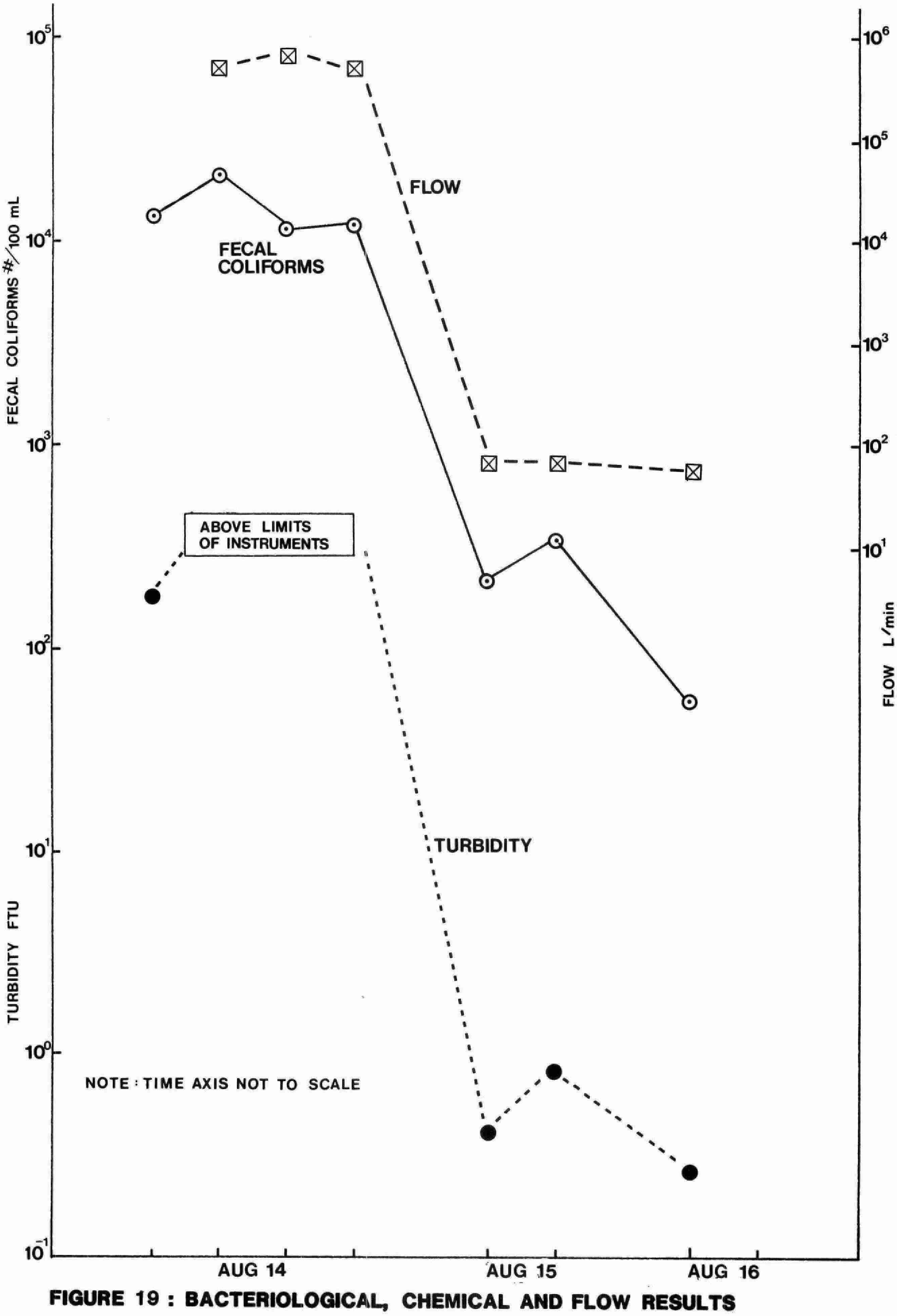


FIGURE 19 : BACTERIOLOGICAL, CHEMICAL AND FLOW RESULTS FOR STATION 15-24, AUGUST 1984

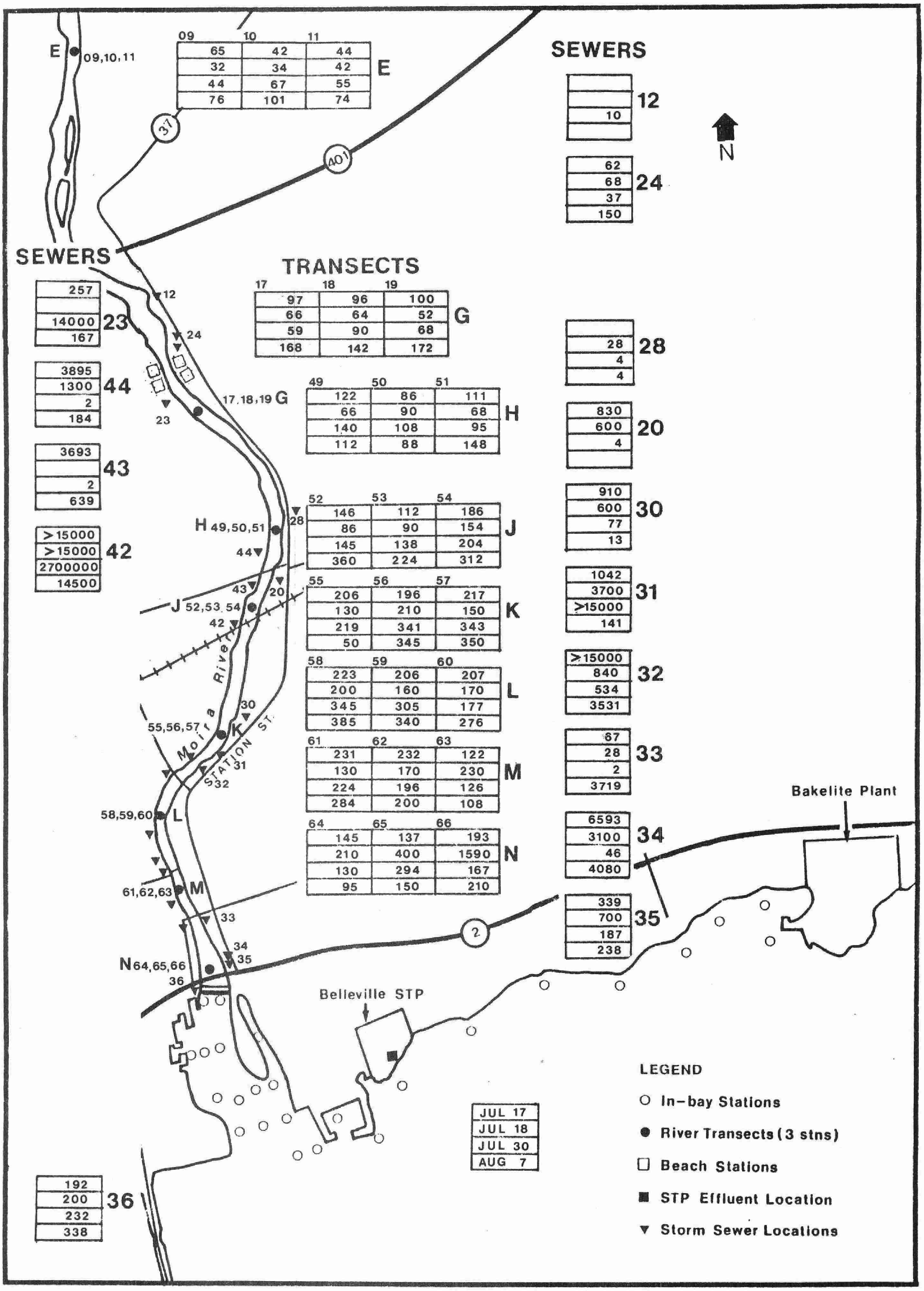


FIGURE 20 : FECAL COLIFORM COUNTS (#/ 100 mL) OBSERVED DURING DRY WEATHER SURVEYS, BELLEVILLE, 1985

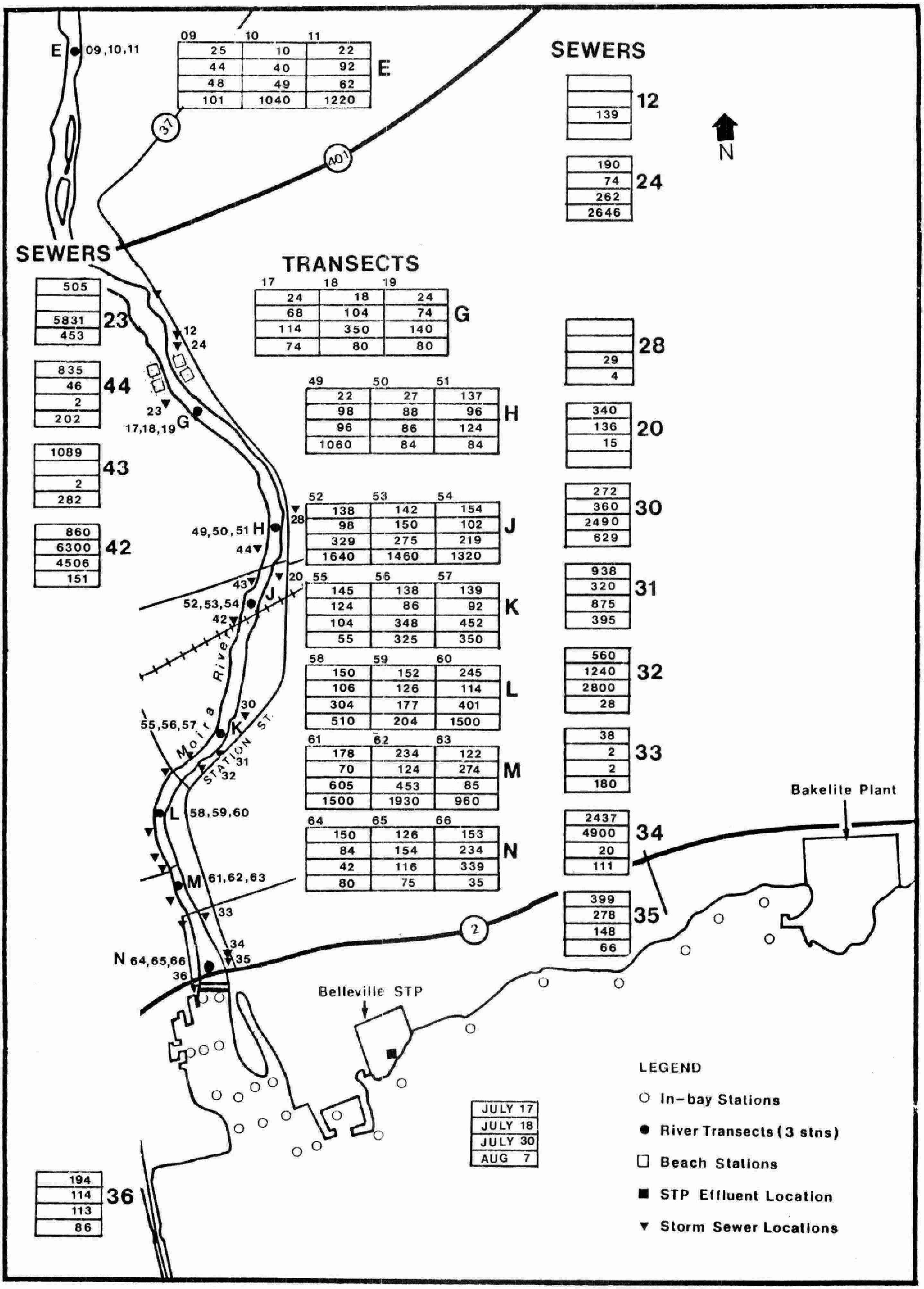


FIGURE 21 : FECAL STREPTOCOCCUS COUNTS (#/ 100 mL) OBSERVED DURING DRY WEATHER SURVEYS, BELLEVILLE, 1985

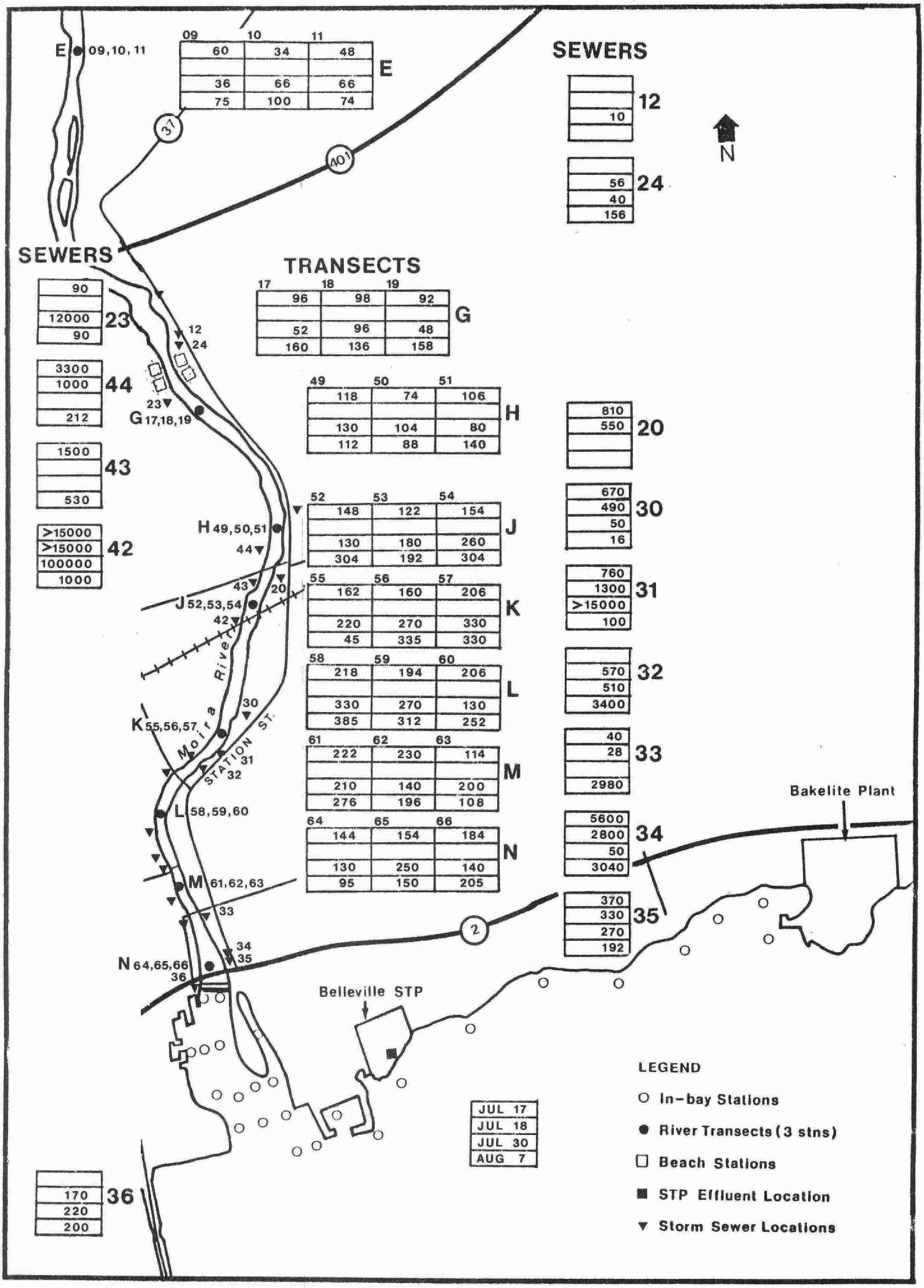


FIGURE 22 : E. COLI COUNTS (#/100 mL) OBSERVED DURING DRY WEATHER SURVEYS, BELLEVILLE, 1985

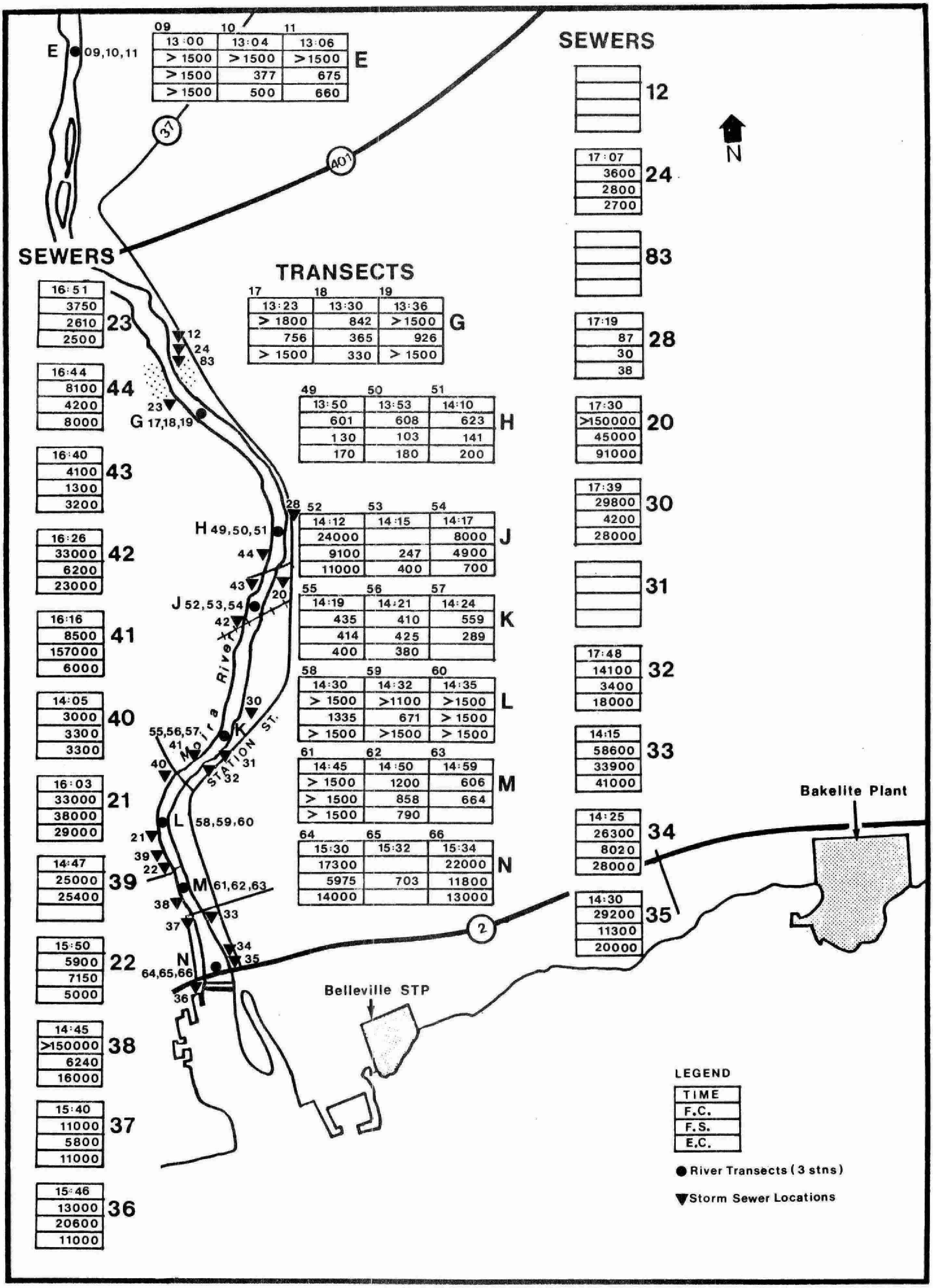
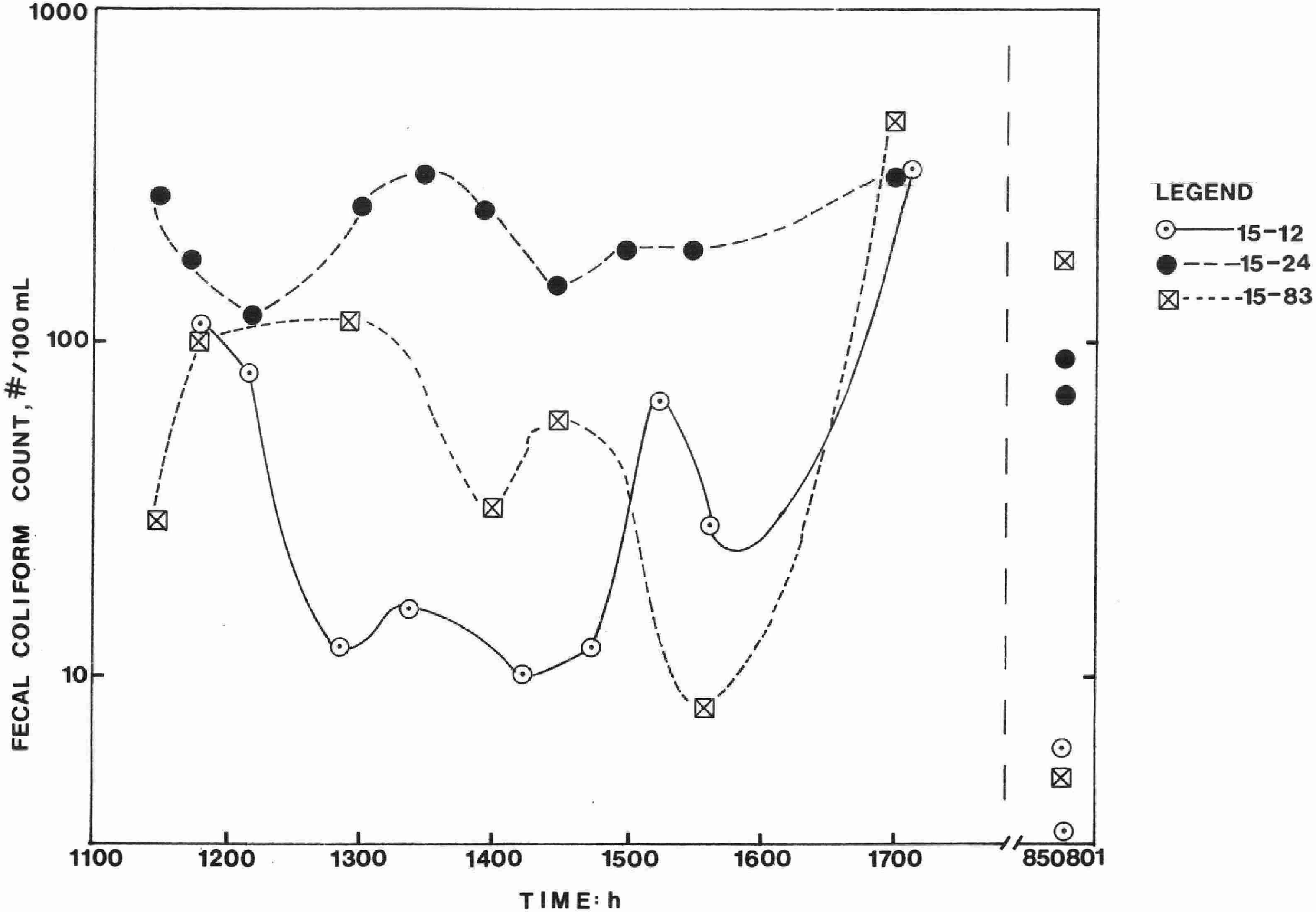


FIGURE 23: SAMPLING TIMES AND BACTERIOLOGICAL COUNTS (#/100mL) AT SEWERS AND TRANSECTS, BELLEVILLE, JULY 15, 1985 (Wet weather conditions: 20 mm rain before and after survey)

FIGURE 24: SEQUENTIAL FECAL COLIFORM COUNTS, JULY 31, 1985, UPSTREAM OF RIVERSIDE BEACH, BELLEVILLE



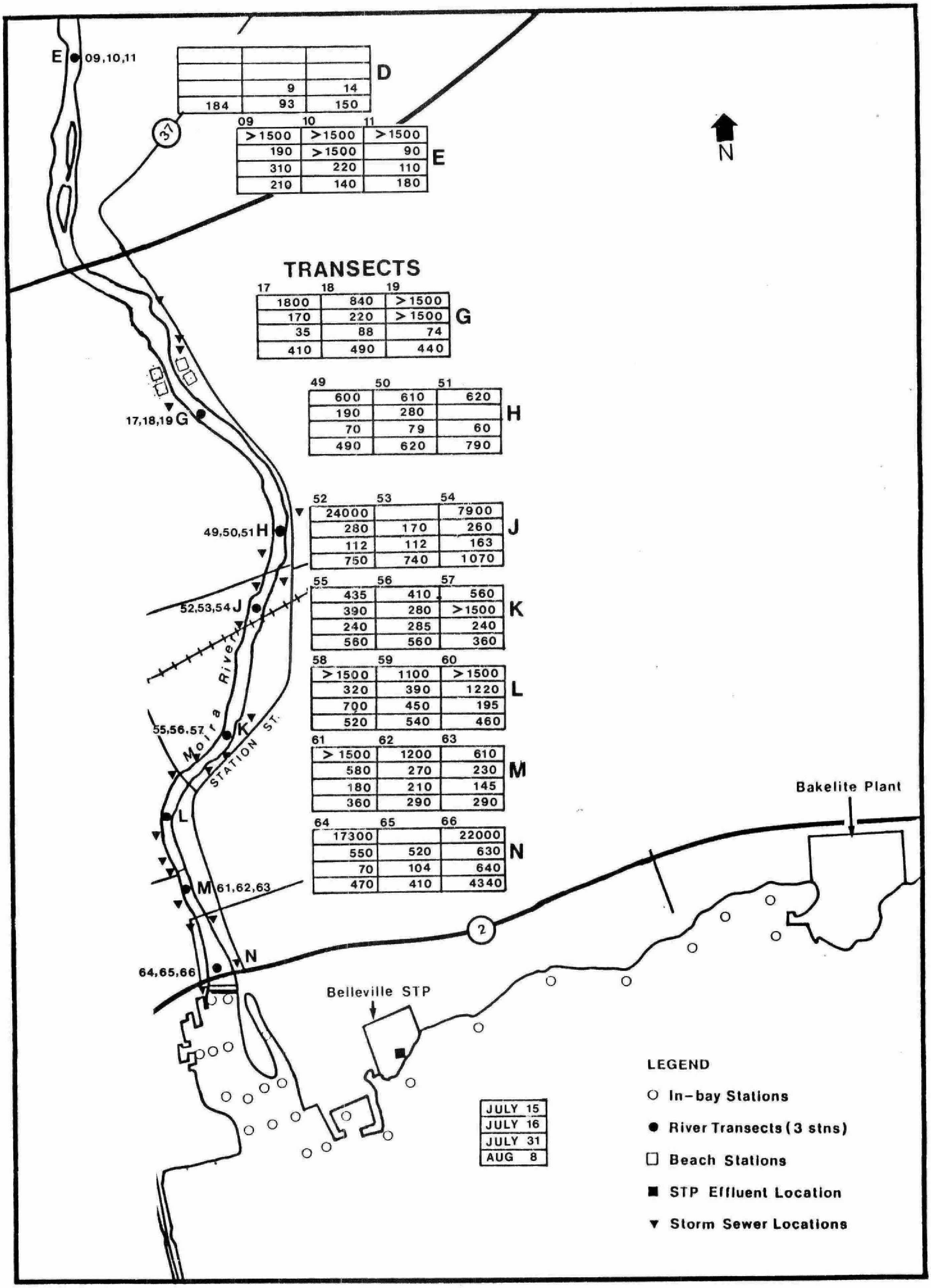
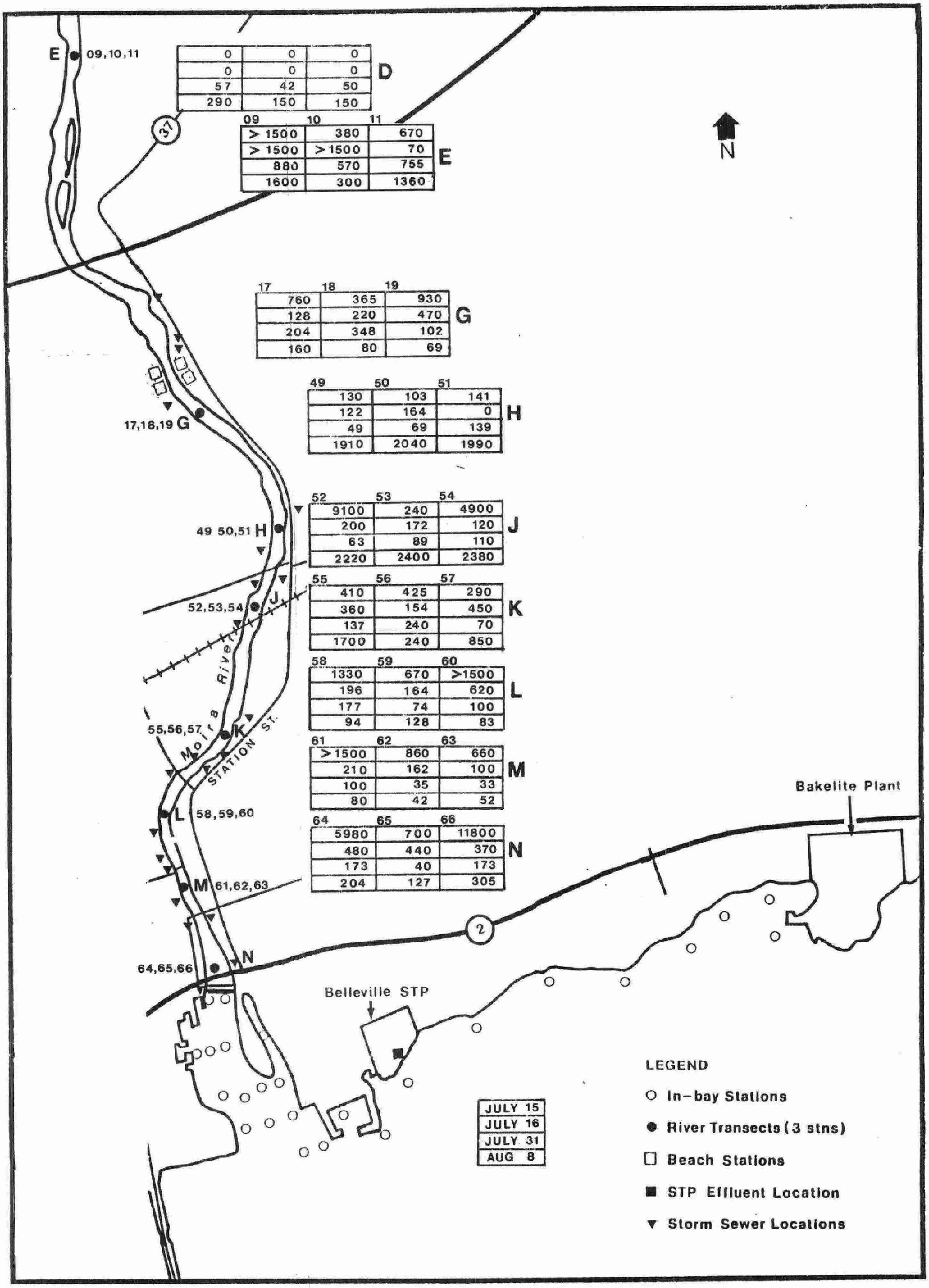


FIGURE 25 : FECAL COLIFORM COUNTS (#/ 100 mL) OBSERVED DURING WET WEATHER SURVEYS, BELLEVILLE, 1985



D

0	0	0
0	0	0
57	42	50
290	150	150

E

09	10	11
> 1500	380	670
> 1500	> 1500	70
880	570	755
1600	300	1360

G

17	18	19
760	365	930
128	220	470
204	348	102
160	80	69

H

49	50	51
130	103	141
122	164	0
49	69	139
1910	2040	1990

J

52	53	54
9100	240	4900
200	172	120
63	89	110
2220	2400	2380

K

55	56	57
410	425	290
360	154	450
137	240	70
1700	240	850

L

58	59	60
1330	670	>1500
196	164	620
177	74	100
94	128	83

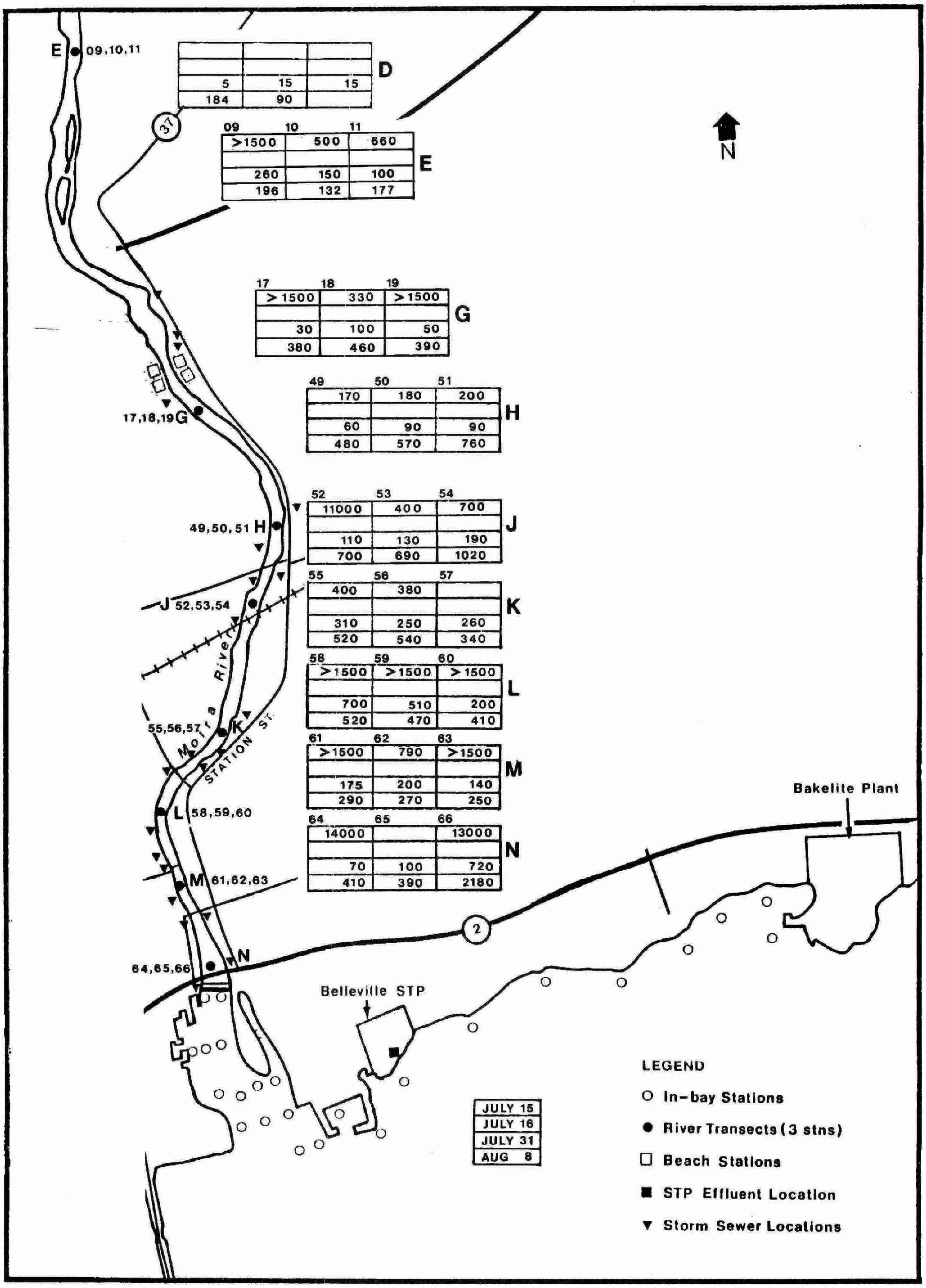
M

61	62	63
>1500	860	660
210	162	100
100	35	33
80	42	52

N

64	65	66
5980	700	11800
480	440	370
173	40	173
204	127	305

FIGURE 26 : FECAL STREPTOCOCCUS COUNTS (#/ 100 mL) OBSERVED DURING WET WEATHER SURVEYS, BELLEVILLE, 1985



D

5	15	15
184	90	

E

09	10	11
>1500	500	660
260	150	100
196	132	177

G

17	18	19
>1500	330	>1500
30	100	50
380	460	390

H

49	50	51
170	180	200
60	90	90
480	570	760

J

52	53	54
11000	400	700
110	130	190
700	690	1020

K

55	56	57
400	380	
310	250	260
520	540	340

L

58	59	60
>1500	>1500	>1500
700	510	200
520	470	410

M

61	62	63
>1500	790	>1500
175	200	140
290	270	250

N

64	65	66
14000		13000
70	100	720
410	390	2180

FIGURE 27 : E. COLI COUNTS (#/ 100 mL) OBSERVED DURING WET WEATHER SURVEYS, BELLEVILLE, 1985

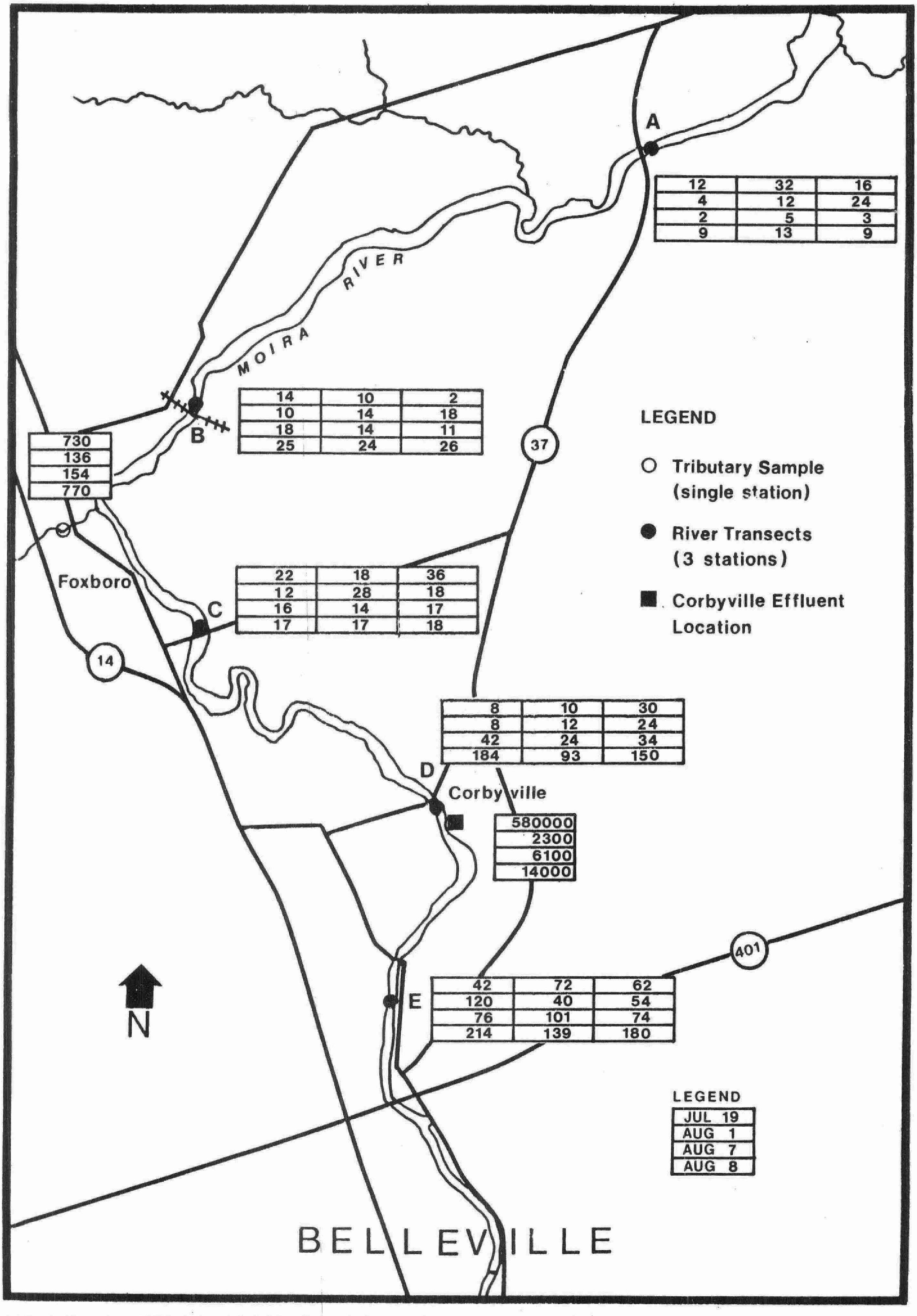


FIGURE 28 : FECAL COLIFORM COUNTS (#/ 100 mL) UPSTREAM TRANSECTS, BELLEVILLE, JULY 19, AUGUST 1, 7, 8, 1985

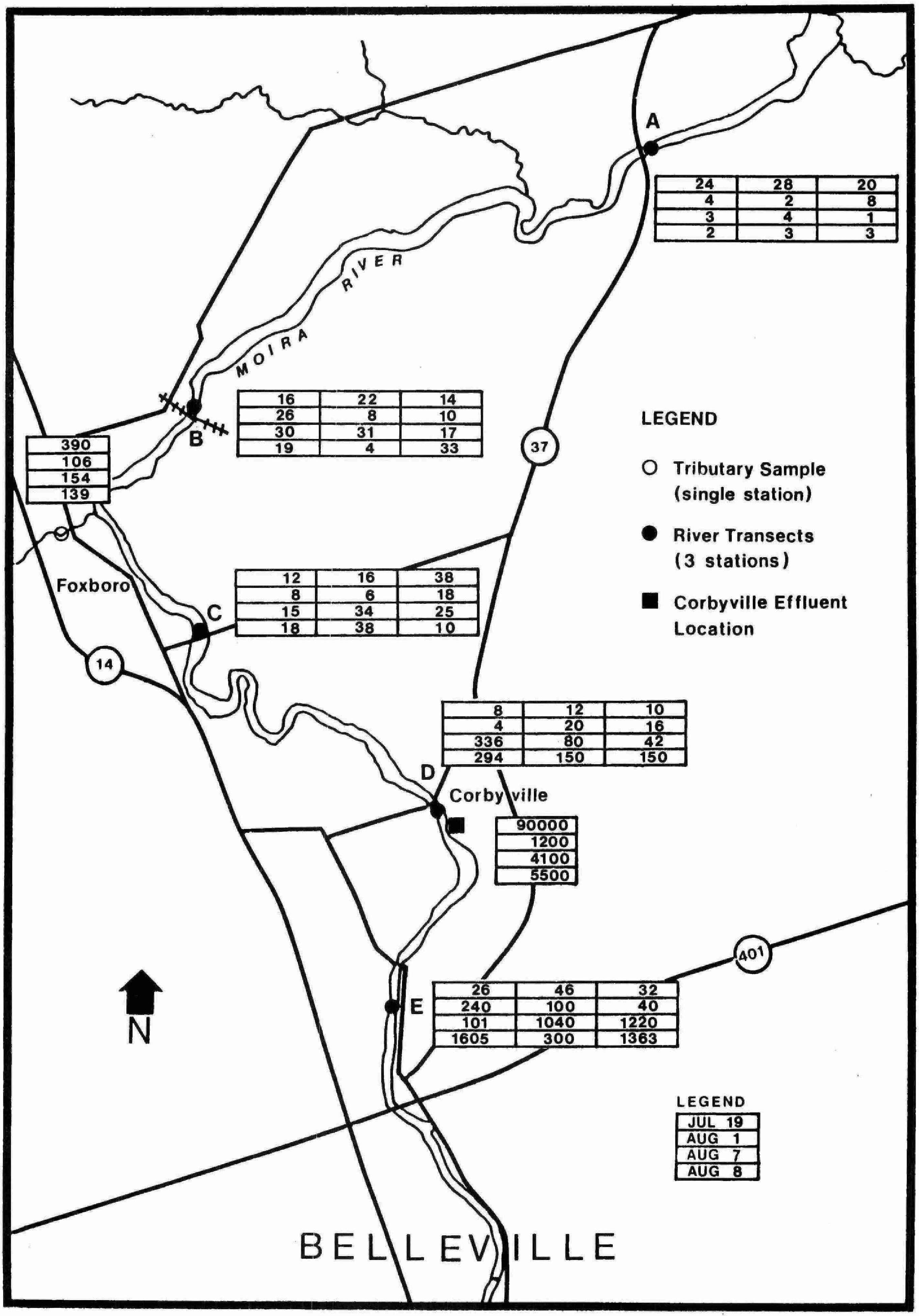


FIGURE 29 : FECAL STREPTOCOCCUS COUNTS (#/100 mL), UPSTREAM TRANSECTS, BELLEVILLE, JULY 19, AUGUST 1, 7, 8, 1985

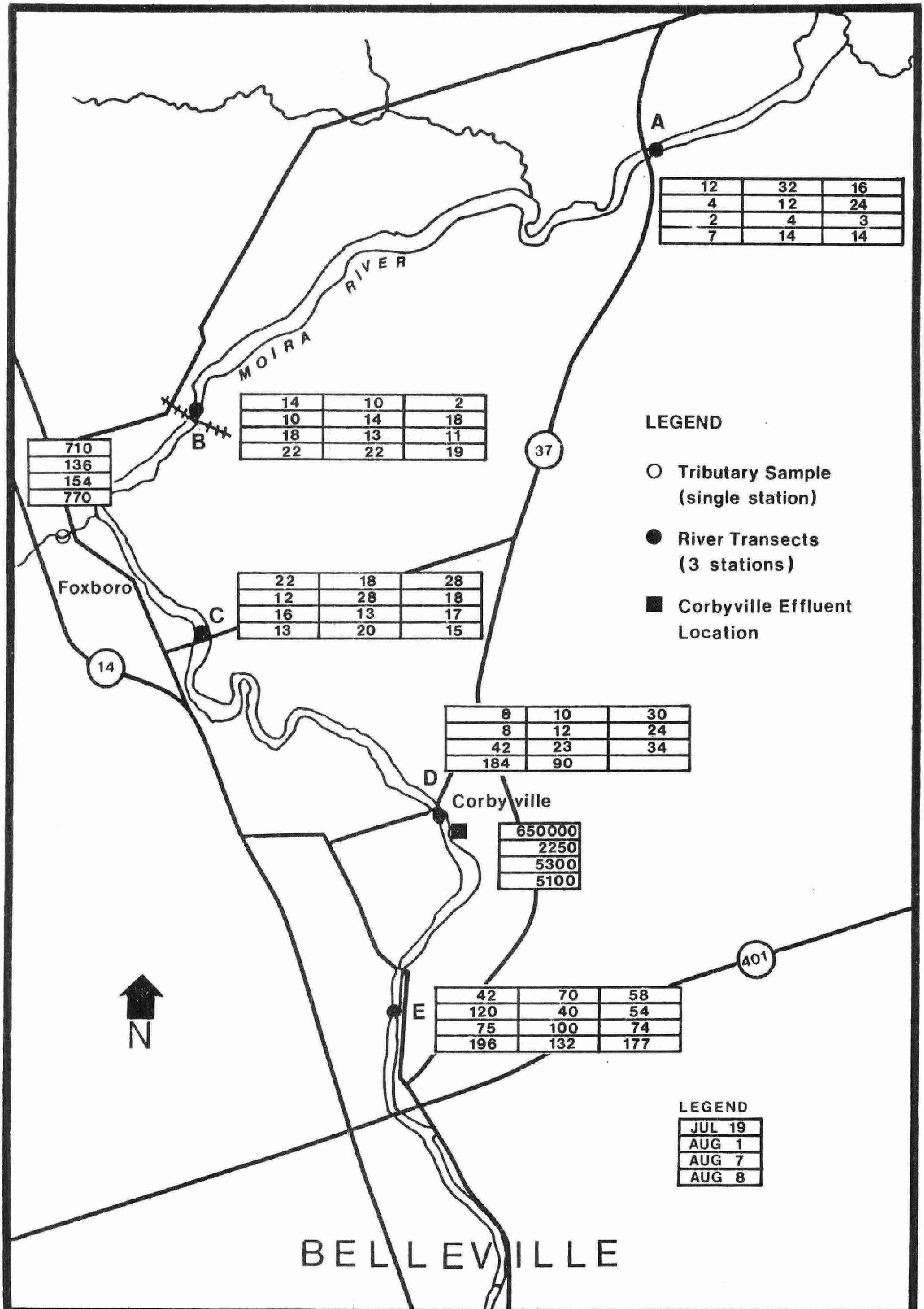


FIGURE 30 : E. COLI COUNTS (#/ 100 mL) , UPSTREAM TRANSECTS, BELLEVILLE, JULY 19, AUGUST 1, 7, 8, 1985

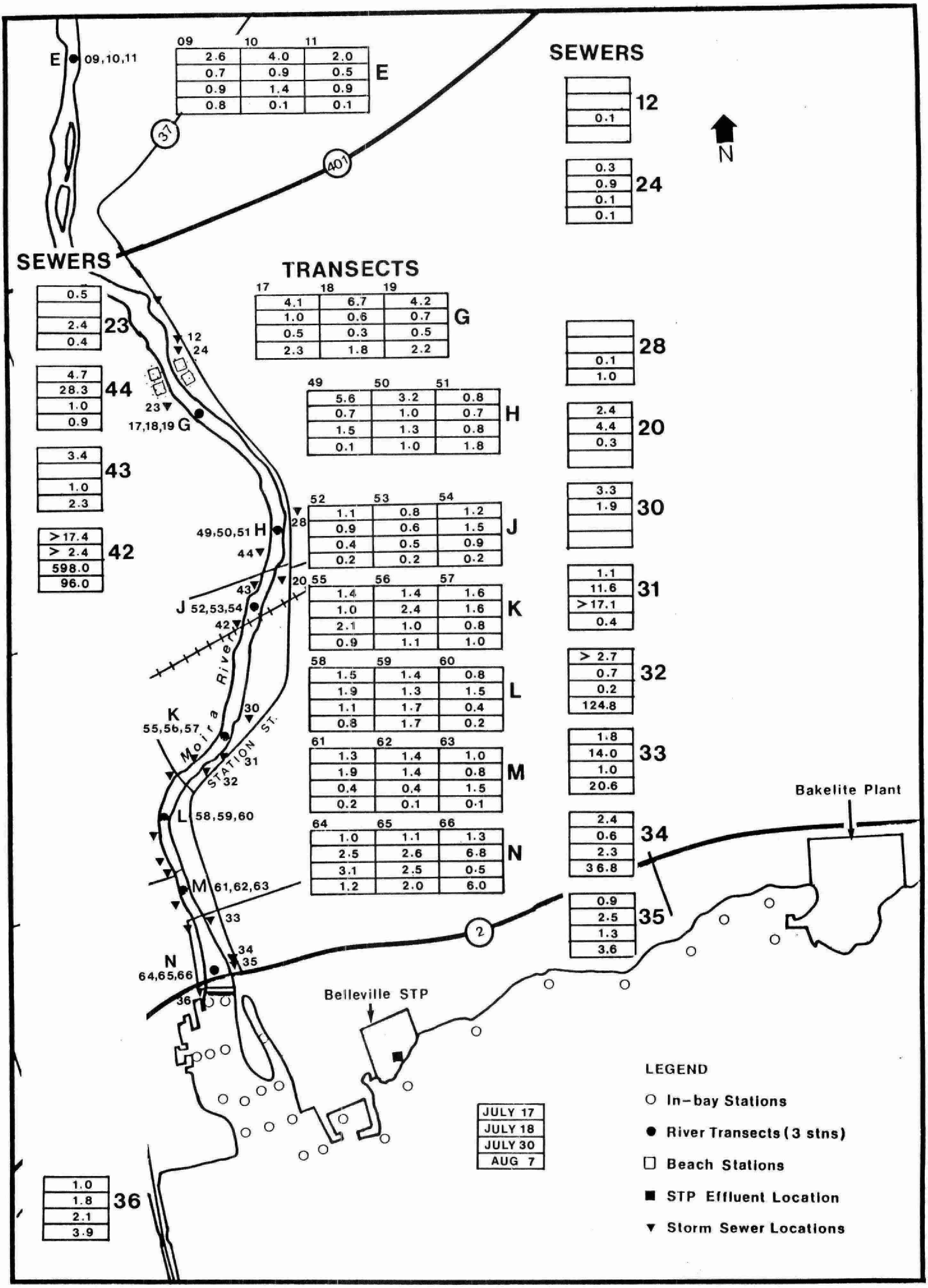
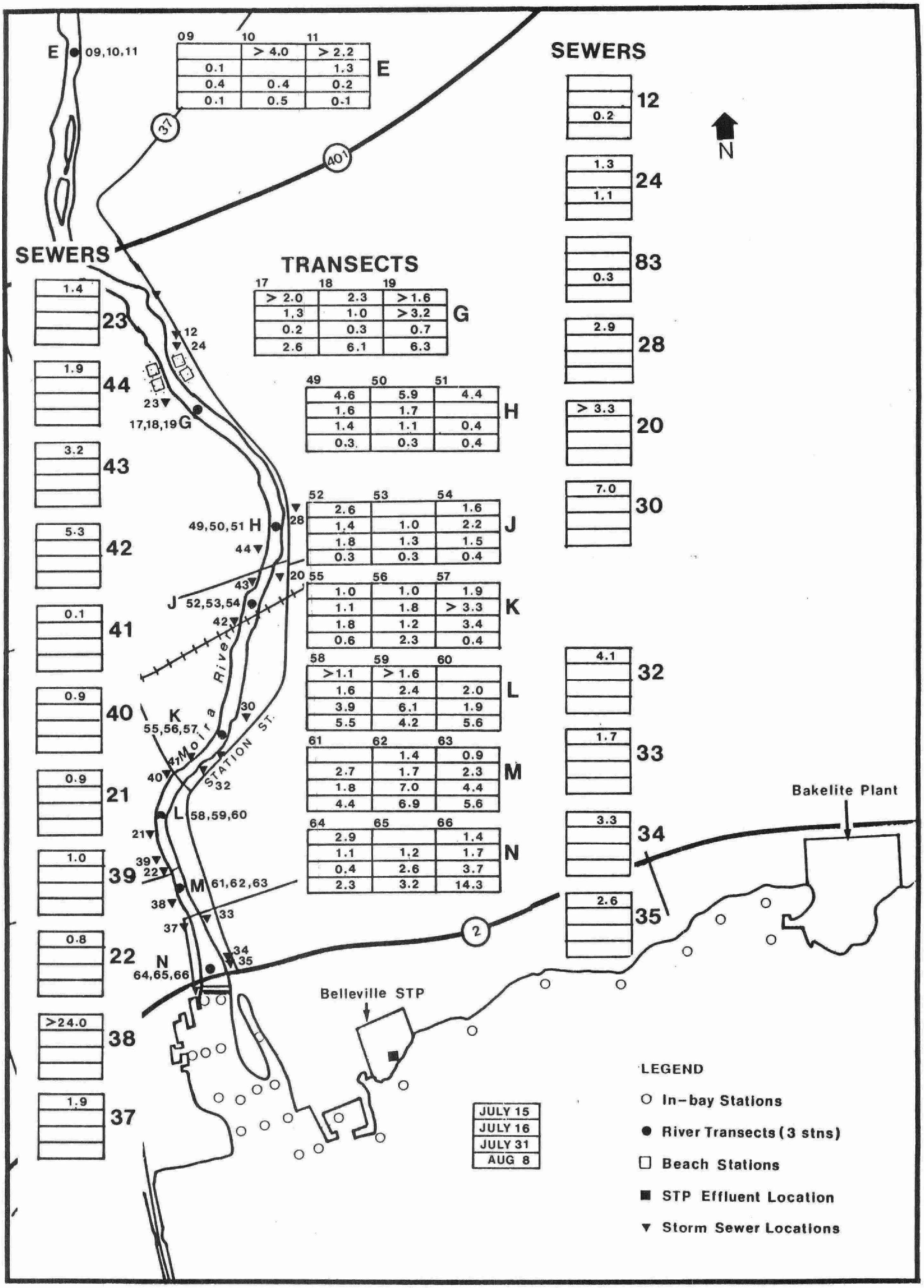


FIGURE 31 : FECAL COLIFORM/ FECAL STREPTOCOCCUS RATIOS OBSERVED DURING DRY WEATHER SURVEYS, BELLEVILLE, 1985



Transects

Transect			
E	09	10	11
		> 4.0	> 2.2
	0.1		1.3
	0.4	0.4	0.2
	0.1	0.5	0.1
G	17	18	19
	> 2.0	2.3	> 1.6
	1.3	1.0	> 3.2
	0.2	0.3	0.7
	2.6	6.1	6.3
H	49	50	51
	4.6	5.9	4.4
	1.6	1.7	
	1.4	1.1	0.4
	0.3	0.3	0.4
J	52	53	54
	2.6		1.6
	1.4	1.0	2.2
	1.8	1.3	1.5
	0.3	0.3	0.4
K	55	56	57
	1.0	1.0	1.9
	1.1	1.8	> 3.3
	1.8	1.2	3.4
	0.6	2.3	0.4
L	58	59	60
	> 1.1	> 1.6	
	1.6	2.4	2.0
	3.9	6.1	1.9
	5.5	4.2	5.6
M	61	62	63
		1.4	0.9
	2.7	1.7	2.3
	1.8	7.0	4.4
	4.4	6.9	5.6
N	64	65	66
	2.9		1.4
	1.1	1.2	1.7
	0.4	2.6	3.7
	2.3	3.2	14.3

Sewers

Sewer	July 15	July 16	July 31	Aug 8
23	1.4			
44	1.9			
43	3.2			
42	5.3			
41	0.1			
40	0.9			
21	0.9			
39	1.0			
22	0.8			
38	>24.0			
37	1.9			
12			0.2	
24	1.3		1.1	
83			0.3	
28	2.9			
20	> 3.3			
30	7.0			
32	4.1			
33	1.7			
34	3.3			
35	2.6			

FIGURE 32 : FECAL COLIFORM/ FECAL STREPTOCOCCUS RATIOS OBSERVED DURING WET WEATHER SURVEYS, BELLEVILLE, 1985